Ecology, Biology and Ethology of Greater Adjutant Stork *Leptoptilos dubius* (Gmelin) in Assam, India

**SUMMARY**

Thesis submitted for the degree of

Doctor of Philosophy in

WILDLIFE SCIENCE

By

Hillardjyoti Singha

CENTRE OF WILDLIFE & ORNITHOLOGY
Aligarh Muslim University
Aligarh (India)
1998
Introduction

Of the 20 stork species in the world, the Greater Adjutant Stork *Leptoptilos dubius* is perhaps the most endangered. Earlier widespread in northern and northeast India, Nepal, Bangladesh, Myanmar, Cambodia and southern Vietnam, this stork is now largely localized in the Brahmaputra Valley, Assam. In the mid 1980 its precarious status was highlighted, and since then, some work has been done in Assam.

Before I started work in 1994, except for some basic information there was no detailed study about the ecology, biology and behaviour of the Greater Adjutant Stork (GAS). The objectives of my study were to know the present status and distribution of the GAS throughout the Brahmaputra Valley, during breeding and non-breeding seasons and study to know the nesting ecology, breeding biology and flocking behaviour GAS during the non-breeding season.

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highways as well as interior places on motor cycle. Information from literature and locals were taken to survey the nesting colonies.

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It seems that the Greater Adjutant Storks are opportunistic feeder and forage in different habitats according to the food availability.
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26th March 1998

Asad R. Rahmani
Supervisor
Dedicated to
my father

Late Tapan Kumar Singha

my friend, philosopher and guide
whose presence in my heart
always inspires me
The Greater Adjutant Stork protecting its future - let us also take it under our wing
ACKNOWLEDGEMENTS

This thesis is not only the result of my individual effort, there are lot of people at the background whose endless support and good wishes have made it possible. It is however difficult to name them all in these limited pages for which I apologize to them. In fact, they are the people I offer my heartily gratitude. I take this opportunity to thank the people of Assam who extended their helping hand and provided me food and shelter during my surveys and during the course of my field study.

I am grateful to the US Fish & Wildlife Service for funding and Ministry of Environment and Forest, Government of India for sponsoring the Stork Project under which I did my study. I am thankful to Mr. David Ferguson, Officer of International Affair of USFWS for taking special interest in this project.

I offer my gratitude to Dr. Malcolm C. Coulter for his valuable suggestions, comments help in data analyses and fruitful discussion.

I am thankful to my field assistant Dwipendra Narayan Dev for his continuous help and company throughout my field work. My thanks to my younger brother Amarjyoti Singha, friends Prasanta K. Bardoloi, Shimanta K. Goswami, Prabin Hazarika, Nabin Bardoloi, Kushal Saikia, Bakul Rahman, Prof. S. Barkataki, Prof. B. Kotoky, Prof. Mrs. B. Goswami and Prof. S. Ahmed for their help and kind cooperation.

I have sincere gratitude to Manoranjan Bora, Prof. Rabin Sarma, his son Bhaben Sarma and their family for allowing me to built the watch tower inside their house compound and Bhadrankanta Gayan for providing all necessary facilities. I am thankful to my aun: Mrs. K. Hazarika, house owner M. Bora and Mrs. K. Bora for all kind of facilities to stay at Nagaon.

I acknowledge Dr. Anwaruddin Choudhury, The Rhino Foundation, Dr. Diptimanta Barooah, Basudha; Manju Barua, Prof. P. C. Bhattacharjee, Dr. P. K. Saikia, Rathin Barman, Bibhab Talukdar, Tapan Deka of Zoology Department, Gauhati University; Chandan Roy, Tezpur Kendria Vidyalaya for their information and help in the field.
My thanks to all forest officials in Assam including Messers. P. Lahan, B. K. Talukdar, P. K. Sharma, N. Ojah, M. Barua, Pallav Deka, G. Chettry, R. K. Das, M. Ali for their help and cooperation.

I offer my sincere gratitude to Dr. Putul Sarmah, Manik C. Debnath, Bidya Deka of Regional Agricultural Research Station, Shillongoni, Nagaon for the meteorological information. I am thankful to Dr. Rezaul Karim for identification of ectoparasite in Greater Adjutant Stork.

I am grateful to all the staff of the Centre of Wildlife & Ornithology, A.M.U. Aligarh for their cooperation. I am thankful to Dr. Salim Javed, co-investigator of the Stork Project and Satish Kumar for their continuous help, comments and advices, without which it would not have been possible to reach this stage. I thank Khursheed Ahmed for checking the meteorological data. I thank Jaseem Bakhsh for his help in the field. I also thank Zameer Ahmed for drawing the maps.

I am thankful to Dr. R. Manakadan, Dr. Y. N. Rao, Dr. S. Alagarajan, Dr. G. Ugra, Mr. S. R. Nayak, Shubhangi and Aboli of Bombay Natural History Society (BNHS) for their suggestions and help. I thank Mehboob Alam for the help in the field. I would like to offer my thanks to all staff of BNHS for their cooperation while writing the thesis.

My special thanks to project colleagues G. Maheswaran and Farah Ishtiaq for their inspiration and all kind of help.

I offer my heartiest gratitude to Dr. Asad R. Rahmani, Principal Investigator of the Stork Project and Director BNHS for over all guidance, advises and inspiration which have made my way easier to reach the goal.

This thesis would not have seen light of today but for one person’s heartily involvement in the final setup of this thesis. A major part of the credit goes to him. I offer my heartiest thanks to that person, my friend Zafar-ul Islam of BNHS for everything.
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The result of the flocking behaviour study during non-breeding season which is very brief compared to the long breeding season shows that the Greater Adjutant Storks form very compact flocks. Synchronization of activities was noticed which shows flock cohesiveness. It was observed that during the non-breeding period, at garbage dumps, most of the storks pass the day resting and feeding.
There was a significant difference of adults and juveniles particularly in foraging activities. Most of the activities of the GAS at two different places were significantly different which shows that habitat condition can influence the behaviour of GAS. It seems that weather fluctuation have very little impact on the activities of storks in garbage dump. Except for some activities, the general trend of the storks involved in different activities at garbage dumps remained almost similar at different time of the day.

It seems that the Greater Adjutant Storks are opportunistic feeder and forage in different habitats according to the food availability.
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Chapter 1

GENERAL INTRODUCTION
Chapter 1

GENERAL INTRODUCTION

Being large, conspicuous, and easily observed, storks are well known birds wherever they occur (Kahl, 1987). The stork family Ciconiidae includes 20 species and is widely distributed, mainly in the Old World tropics. The family has three distinct subdivisions or tribes: the Wood Storks/Openbill group (six medium sized species), 'typical' storks (five to seven species) and 'giant' storks (six species).

The genus *Leptoptilos* which belongs to the 'giant' storks has three species: *Leptoptilos dubius* (Greater Adjutant Stork), *L. javanicus* (Lesser Adjutant Stork) and *L. crumeniferus* (Marabou Stork). The former two are found in tropical Asia, while the third one is found in tropical Africa.

The richest stork diversity of the world is found in southeast Asia (Luthin, 1987). Of the 20 stork species, 11 are found in this region among which nine species are reported from India (see Luthin, 1987; Kahl, 1987). Except the Painted Stork *Mycteria leucocephala*, eight species are found in Assam (Saikia and Bhattacharjee, 1993, Choudhury 1990), of which the Greater Adjutant Stork *Leptoptilos dubius* is an endangered species. Luthin (1987) has pointed out that among storks it deserves the highest conservation priority.

The main generic characteristics are: the head and neck of the members of this genus are naked except for sparse scattered hair-like feathers, and the crown is bald (Ali and Ripley, 1987). The Greater Adjutant Stork is the largest and 'ugliest' Asian Stork
standing 120-150 cm to the top of the head when erect. Its general colour is slaty-black, grey and white, with a nearly featherless head and neck, a massive wedge-shaped bill and naked ruddy pinkish gular pouch, 25-35 cm long when inflated, hanging from the front of the neck (Ali and Ripley, 1987; Hancock et al., 1992). The upper parts are slate grey, with a pale band along the wing formed by the pale gray greater secondary coverts. The underparts are white. Dorsally there is a ruff of white feathers around the base of the neck, surrounding a red or orange air sac. The undertail-coverts are white at their bases and dark smoky grey at their tips.

The iris is white to yellowish white. The bill varies from pale yellowish to greenish, more reddish near base. The legs and feet are actually horny brown to dark grey, but often appear pale greyish white or chalky white because they are coated with uric acid from excreta.

It was named 'Adjutant' because it walks with the deliberate, measured gait of a military adjutant. Though more common Assamese name is 'Hargila' (= bone swallower), it is known in different parts of Assam by different names: Hodong, Dhodong, Jomtokola, and Bamuni bartokola.

Outside India, the Greater Adjutant Stork (GAS) has been found in Nepal, Bangladesh, Myanmar, Cambodia and southern Vietnam (Baker, 1929; Ali and Ripley, 1987; Fleming, 1979). Up through the 1930s, large colonies were reported near Shwaygheen, in the Pegu district of southern Myanmar (Baker, 1929) and it was thought that perhaps all population of GAS went there each year during winter for breeding. These large colonies have been destroyed (Smythies, 1953) and no individual has been reported in
recent years (Luthin, 1987). In late nineteenth century another large breeding colony of GAS was found in the Sundarban mangrove forests of Bangladesh (Baker, 1929). It is thought to be extinct now (Khan, 1984; 1987). However, in the recent past, few storks are reported from Nepal and Bangladesh (see Rahmani et al., 1990).

The Greater Adjutant Storks were also common in Chiang Rai Province of northern Thailand in the nineteenth century but now the number is much reduced (see Hancock et al., 1992). Very recently, a confirmed breeding population of GAS has been reported from Cambodia and a range of 100-150 birds may be present there (Anon., 1994).

In India, this stork has been found in Assam, Orissa, Rajasthan, Nepal terai and the Gangetic plain (Ali and Ripley, 1987) but it has now disappeared or has become extremely rare in the whole of its distributional range (Rahmani et al., 1990). They report that outside Assam, till 1980s the GAS was found in a few places in Rajasthan, Tamil Nadu, Delhi, Bihar and West Bengal but not in Uttar Pradesh, Madhya Pradesh, Andhra Pradesh and Orissa. As late as 1940s, large flocks of GAS were seen scavenging on city refuse in Calcutta (Ali and Ripley, 1987; Hancock, 1989) which declined very fast in later years. Some ornithologists declared that this species was undoubtedly on the verge of extinction (Luthin, 1987; Hancock, 1989).

Prior to Rahmani (1989) and Saikia and Bhattacharjee (1989a, 1989b), no proper information about the status and distribution of the GAS in Assam was available. Their preliminary surveys drew attention to the stork specialists, attention to the fact that the major stronghold of the GAS of the world was in the Brahmaputra Valley of Assam.
Basic information on ecology and behaviour of this conspicuous and massive bird is available in Ali and Ripley (1987) and Kahl (1966b, 1970, 1971, 1972a, 1974). Probably due to its rarity, detailed study of its ecology and behaviour was not done. In November 1989, Saikia and Bhattacharjee (1990a, 1990b) discovered the first GAS breeding colonies outside protected areas. They subsequently collected initial information about nesting and breeding. Later, Barooah (1991) also added more nesting colonies of GAS to the list.

Before I started work on this species in 1994, no literature was available about detailed study of its ecology, biology and its behaviour. Only recently Saikia and Bhattacharjee (1996a, 1996b) and Bhattacharjee and Saikia (1996) have published a detailed account of this bird. In this thesis, in addition to presenting my own findings, I have compared their finding also with my results.

The objectives of my study and methods to accomplish them are stated below:

I wanted to know the present status and distribution of GAS throughout the Brahmaputra valley, Assam during breeding as well as non-breeding season. I did an extensive survey from one end of the valley to the other, in the first year of my study (1994-95) during the breeding season of the GAS. This survey provided me the basic information to select a site for intensive study of nesting ecology and breeding biology in the latter two breeding seasons. Besides the winter survey (1994-95), I also did random surveys in 1996 during the non-breeding season.
In addition to counting the storks, I was also interested to know the number of nests and the nesting ecology of GAS throughout the study area. So, along with the population survey, simultaneously I also carried out nest survey. Later, for two successive nesting seasons I concentrated my study on nesting ecology in the intensive study site at Nagaon.

The breeding biology was almost unknown prior to start of my work. I intensively studied breeding biology of GAS in two consecutive breeding seasons.

In the earlier literature, the GAS has been described as scavenging during the non-breeding season in summer. But their flocking behaviour in the post-breeding season was poorly known which encouraged me to study this aspect also. For this purpose I selected two places: urban garbage dump at Guwahati and rural garbage dump at Nagaon.

I have fulfilled the objectives of the study and they are presented in this thesis. The findings are organised in five chapters (excluding the first one, i.e., Introduction). The second chapter, Study Area, describes all the sites of field observations and the intensively study site. In the third chapter, I have presented the present status and distribution of GAS in the Brahmaputra valley. The intensive study of nesting ecology and breeding biology, which are the main bulk of my thesis are presented in the fourth and fifth chapters respectively. And the last chapter deals with the flocking behaviour of GAS during non-breeding season. All the related literature have been reviewed in the respective chapters.
Although I tried to cover all the general aspects of the GAS, yet I feel there is plenty of scope to study this species from other angles too. My study comprises only one survey during the breeding season to know the present status and distribution. However, for a better understanding of population fluctuation as well as changes in the nesting habitats, a continuous long term study is required.

The experiment with ringing or radio telemetry would be useful to know their home range, foraging distance from nesting colony and minimum age of new breeder. I think a minimum of five continuous years’ data are necessary to study the reproductive success of the GAS.

There is very little literature on Greater Adjutant Stork in particular, and storks in general. Whatever relevant literature is present, is quoted in different chapters at appropriate places.
Chapter 2

STUDY AREA
CHAPTER 2

STUDY AREA

2.1 INTRODUCTION

The status, distribution, ecology and behavior of the Greater Adjutant stork *Leptoptilos dubius* was studied in the Brahmaputra valley (25°44'-27°55'N and 89°41'-96°02'E), Assam. The political boundary of Assam is demarcated by Bhutan and Arunachal Pradesh in the north; a part of Arunachal Pradesh in the east; Nagaland and Manipur in the south-east; Mizoram, Tripura, Meghalaya in the south; and Bangladesh and West Bengal in the west (Fig. 2.1). There are two major river-systems in Assam: the river Brahmaputra traverses more than 600 km through the entire state dividing longitudinally almost into two halves; and the river Barak in the southern Assam. The Brahmaputra valley is a well-demarcated physical unit from the rest of India within the girdle formed by the Eastern Himalaya, Patkai, Naga Hills, the Garo-Khasi-Jaintia and the Mikir Hills (Singh, 1991). Extending from the eastern most tip of Upper Assam near the bend of the Eastern Himalaya to the west of Dhubri on the border of Bangladesh, the valley (about 720 km length x 80 km wide) covers an area of about 56,274 sq km.

2.2 PHYSIOGRAPHY

Physiographically the major part of Assam is plain, being dominated by the Brahmaputra valley which covers more than 60% of the total area of the state (Choudury, 1994). The valley mostly built by the flood plain of the Brahmaputra and its tributaries is almost a flat level plain with very low slope from its north-east corner at Sadiya to Dhubri in the west. The general level of the valley ranges from 130 m in the
Fig. 2.1. Districts of the Brahmaputra Valley in Assam. The Karbi-Anlong district (No. 17) was excluded from the survey as most parts of this district are highlands.
east to 30 m in the west with a fall about 12 cm per km. The valley in its northern
margin is characterised by a steep slope, having an almost immediate fall from the
foothills of the eastern Himalaya, but the southern margin has a gradual fall from the
southern hill ranges.

The valley is fairly wide particularly in Upper Assam in the east, with an average width
of 80-100 km, but it narrows down to about 55 km in its middle part. Beyond this it
widens west ward, for the plain of the Kapili river only to narrow down to about 65 km
on an average between the Shillong plateau and Bhutan Himalaya. The valley again
widens to the west until it merges with the North Bengal plain.

An interesting geomorphological feature of the valley is the presence of isolated
hillocks on both the banks of the river; in some places at the very edge of the river.
There is also a marked difference between the physiography of the north and south
bank of the river. The north bank valley is much wider and the innumerable tributaries
have conspicuous meandering courses leading to the formation of beels and ox-bow
lakes and huge marshy tracts. The southern part of the valley is less wide and uneven
and the tributaries in the south-east are considerably larger. In the eastern part of the
southern section of the valley the tributaries take meandering courses and there are
many beels and ox-bow lakes (fig. 2.2). There are about 1400 wetlands in Assam and
majority of them are in the Brahmaputra valley. Another physical characteristic of the
Brahmaputa is that there are numerous river islands including Majuli, the largest river
island (929 sq. km) in the world (Singh, 1991).
Beel – 8

Total area of beel = 1298948 Hectares

Fig. 2.2. Wetlands (beels) in the Brahmaputra Valley, Assam. (Source: ARSAC, Guwahati).
The valley can be divided into four distinct zones (Fig. 2.3). In the north bank, the bhabar zone lying along the Eastern Himalaya foothills is formed as a result of the coalescence of alluvial soils. Immediately south of the bhabar zone is a flat narrow belt, called the terai zone where the water seeps out from the former. This zone has tall grasses with damp ground. Immediately south of the Terai zone at about equal distance from the Brahmaputra to the south and hills of the north lies a strip of highland zone from east to west. It is the most densely populated area and supports extensive paddy fields.

In both the immediate banks of the Brahmaputra, except where the ground rises to the occasional hillocks is the flood plain. It is swampy and contains numerous beels and ox-bow lakes. South of the flood plain zone in the south bank of the Brahmaputra a narrow strip of high land is found in the western part of the valley which becomes wider towards the east.

2.3 DRAINAGE AND FLOOD

The Brahmaputra river has more than hundred tributaries in Assam out of which fifteen major tributaries are in the north bank and ten in the south bank. Many of these tributaries are large rivers with sizeable catchment areas and bring huge amount of water and silt particularly when in spate, with the result that, in the monsoon the Brahmaputra resembles a 'slowly moving lake', in parts being as wide as eight km from bank to bank. The Brahmaputra raises its bed by heavy silt discharge and fills it every year by lateral erosion. These hydrological conditions naturally result in the swelling of the rivers causing floods. Thus, floods in the tributaries along with the main river have become almost an annual occurrence.
Fig 2.3. Physiographic divisions of Assam.
2.4 CLIMATE

The climate of the Brahmaputra valley is mainly controlled by five factors: (1) the orography, (2) the alternating pressure cells of North-West India and Bay of Bengal, their eastern and north-eastern periodic oscillations, (3) the predominance of maritime tropical air-mass, (4) the periodic western disturbances and (5) the local mountain and valley winds (Barthakur, 1968). The sub-tropical locational and positional significance with its mountain and plateau girdle, and an opening to the west are particularly contributive to its climatic character. The climatic conditions in the Brahmaputra valley exhibit a major deviation which can be classified as ‘humid meso-thermal Brahmaputra valley type’ (Barthakur, 1968).

On the basis of variations of temperature, rainfall and winds, the year in the region may be divided into four distinct seasons:

(a) Winter season (December-February): This season is characterised by cool weather and frequent morning fog. Temperature remains well above 12.8°C, the average diurnal range seldom exceeding 5.5°C. January is the coldest month. The total amount of rainfall in this season seldom exceeds 11 cm. However, casual showers interrupts this weather which lower the temperature and bring cold spells.

(b) Pre-monsoon or Summer season (March-May): It is transitional between relatively dry winter and wet summer, and is characterised by a rapid rise of temperature. As the season advances, the amount and frequency of rainfall increases due to frequent thunder-showers with hail-storms. These thunder-storms are locally
known as *Bardoichila*. The total rainfall during this season is about 52 cm. The average temperature of this season is 23 °C with an average diurnal range of about 6.1 °C.

(c) **Monsoon season (June- September):** This season is characterised by very high humidity (82±5%), with variable surface winds, cloudy sky and incessant rains associated with thunder-storm. The average temperature is 27.17 °C with an average diurnal range of over 6 °C. The average rainfall range is 286 cm. August is the hottest month.

(d) **Retreating monsoon season(October-November):** This season is characterised by fair weather, falling of temperature and morning mist and fog. The average temperature is 27 °C and relative humidity is about 82%. The rainfall does not exceed 15 cm.

2.5 **VEGETATION**

The flora of Assam comprises the following types of forests (Kanjilal, 1934).

(a) **Evergreen forest:** It consists of large number of species, chiefly of the following families- Dilleniaceae, Anonaceae, Magnoliaceae, Guttiferae, Leguminaceae. The forests generally present a three storey appearance. The fast growing tall trees occupy the top storey which include *Dipterocarpus turbinatus*, *Artocarpus chaplasha*, *Tetrameles nudiflora* (Kanjilal, 1934; Rao, 1974). The middle storey is formed either by a gregarious species, such as *Mesua ferrea* or a large number of mixed species of the families mentioned above; e.g., *Dillenia indica*, *Daubanga grandiflora*, and *Terminalia*
myriocarpa. The third and lowest storey consists of small trees and shrubs; e.g., Acacia, Bauhinia, and Unona.

(b) Deciduous forest: It includes mainly the Sal Shorea robusta forests which are mainly found in the western and middle Assam. The associated species of trees are Bombax ceiba, Albizzia spp. Adina cordifolia and few others.

(c) Swamp forest: This type of vegetation is found along the margin of or in the beels or wetlands. Members of Nymphaeaceae, Lamnaceae, and Araceae are common in marshes. The grasses like Typha elephantia, Arundo donax, and Phragmites communis also occur. Shrubs of Crataeva lophosperma, Eugenia cuneata, Homonia riparia with stunted trees of Salix tetrasperma form the other common elements of these swamps.

(d) Grassland: Pure grasslands are of two types in the Brahmaputra valley- the riparian tracts and the belts of low rainfall. The grasses of the former are very tall, some being up to 6 m. in height belong to the genera: Saccharum, Anthistoria, Erianthus, Arundo, and Phragmites. They cover extensive tracts along the large rivers, especially where the banks are low. In the dry belts, grasses are generally smaller in size and are represented by Imperata, Paspalum, Andropogon, and Erianthus.

Besides the above vegetation types, there are some riparian forests along the large river banks and in those alluvial tracts which are inundated during monsoon. This type
comprises Dalbergia, Acacia, and Bombax. In addition to these, the valley is rich in bamboo (Dendrocalamus and Bambusa) which occur throughout the valley.

2.6 INTENSIVE STUDY AREA

Nagaon (26°21' N, 92°45' E) is a small town situated almost in the middle of Assam (Fig. 2.4) and surrounded by thickly populated Assamese villages. In the township two nesting colonies - North Haibargaon and Khutikatia which were approximately 4 km. from each other, were selected for intensive study of breeding biology and nesting ecology of GAS for two successive seasons (1995-'96 and 1996-'97). These are traditional breeding sites and locals say that these have been used for nesting for many years. These places are semi-urban areas with thick human habitations. New buildings are being built very near to the nesting trees. The nesting trees are private property and are located just near the settlements. The North Haibargaon colony is intersected by a few busy public roads also. A small river named Kolong flows about 100 m from the colony. On the other hand, the Khutikatia colony is about 100 m away from the national highway 31 which runs parallel to the colony.

The nesting colonies are a combination of isolated patches of forest and mix plantations. The area is mostly dominated by bamboo Bambusa sp. and betelnut Areca catechu. Shrubs are present under these tall trees. The tree species were: Albizia lucida, Artocarpus heterophyllus, Artocarpus lacoocha, Cedrella toona, Moringa oleifera, Tamarindus indica, Cassia fistula, Mangifera indica, Ficus glomerata, Garcinia spp., Premna benghalensis, Syzygium cumini, Phyllanthus emblica, Ficus religiosa, Alstonia scholaris, Mitragyna parvifolia, Bombax ceiba, Trewia nudiflora, and Streblus aspera (see also Appendix 4.3).
Fig. 2.4. Location of different townships during the summer census of the Greater Adjutant Stork (1996). The map also shows the intensive study site at Nagaon (No. 4) and flocking behaviour study sites at Guwahati (No. 3) and Nagaon (No. 4).
2.7 WINTERING GROUNDS

2.7.1. Regular feeding sites

There are some regular feeding sites in the Brahmaputra valley where GAS winter during the non-breeding season. These sites are situated in some major townships on both the banks of the Brahmaputra. These are either near some animal slaughter houses or in the garbage dumps. There are some other places also near the fish and meat market which are in the heart of the busy town. According to the locals these are the sites which have been traditionally used by GAS year after year in the non-breeding season. The animal slaughter houses are generally situated at the outskirts of the town near an open field where GAS and other scavengers are found together. In every such sites there are either some trees or high buildings where they can perch. The GAS foraging sites near fish and meat market are always crowded by man; however there are some isolated open spaces or water pools adjacent to the market.

2.7.2 Flock behaviour study sites

The flock behaviour study was done in two places at Guwahati (26° 11'N, 91° 47'E) and Nagaon (26° 21'N, 94° 07'E).

Guwahati (Barsapara)

It is a huge garbage dump (~800 sq.m.) at one end of Guwahati city. Everyday 70 to 80 trips of trucks bring wastes (two to three tonnes per trip) to this dumping centre. Since 1976, when wastage dumping started at this centre, it has become a regular foraging ground for scavengers. Besides GAS, cows, goats, dogs, pigs, common
mynas, pied mynas, jungle mynas, pigeons, house sparrows, cattle egrets, vultures and crows forage here. In addition to the animals and birds, many garbage collectors work everyday. They are familiar with the animals and birds.

**Nagaon (Sialmari)**

This is a permanent and regular feeding ground in Nagaon township, about 7 km. and 4 km. from North Haibargaon and Khutikatia nesting colony respectively. It is a bone collecting place, comprising agricultural fields, barren field, a small rivulet 100 m away from the bone dump and a dry land on the other bank of the river. This dry land gets inundated during heavy monsoon and occasionally agricultural practices are also done. Every night, inedible parts of slaughtered cattle and their bones are brought from the town and dumped here. The stomach content and other meat parts are thrown over the ground and bones are collected in an upside open bamboo case. Most of the food is devoured by jackals and dogs at night and only a small amount of food is left for storks, vultures and crows. Intensive study was done on GAS in the dry barren land on the opposite bank of the river, 200 m from the bone store bamboo case.
Chapter 3

POPULATION: STATUS AND DISTRIBUTION
Chapter 3

POPULATION: STATUS AND DISTRIBUTION

3.1 INTRODUCTION

Population ecology deals with the numbers of animals that can be counted or estimated in natural populations; and the essence of the science is to explain these numbers (Andrewartha, 1970). Before starting a study of any species, knowledge of its population in the study area is essential to know its range, distribution pattern and status.

An understanding of stork biology and status is required for their conservation (Coulter, 1987). In recent years some studies on certain ecological aspects of aquatic birds, including stork distribution in Assam have been done (Saikia and Bhattacharjee, 1989a, 1989b, 1993; Raj, et al. 1992). A preliminary survey of Adjutant storks in Assam was done by Saikia and Bhattacharjee (1989b). Rahmani (1989) and Rahmani et al. (1990) also have briefed about the status of Blacknecked and Greater Adjutant storks in the Indian subcontinent. During wetland bird survey from January 1985 to January 1993 in 66 major wetlands in the Brahmaputra valley in Assam, Saikia and Bhattacharjee (1993) recorded seven stork species among which four are endangered namely *Ciconia nigra*, *Ciconia ciconia*, *Ciconia episcopus* and *Ephippiorhynchus asiaticus*. They were found only in sanctuaries and national parks and in few small townships.

Although presence of GAS has been reported from the Brahmaputra valley, comprehensive report about its recent status and distribution was not available till the
initiation of my work in 1994. Of late, Bhattacharjee and Saikia (1996) have presented population trend of GAS in five years (1989-94) in the Brahmaputra valley including the protected areas. I surveyed GAS during 1994-95 breeding season and 1996 non-breeding season. In this chapter, I am going to discuss about the latest status and distribution of GAS in the Brahmaputra valley with future scope to continue further study in this regard. Besides this, information regarding random visits to the breeding colonies in 1995-96 and 1996-97 also have been presented here.

3.2 METHODS

3.2.1 Survey during breeding season (1994-95)

The survey was done from 8 January to 31 March 1995. Part of the data were collected from an earlier survey during November and December 1994. The areas covered in November and December 1994 were not repeated in 1995. Data of both these periods were pooled. The survey was of roadside counts. I followed the national highways by motorcycle and counted stork(s) on both side of the road as far as I could see them (Fig. 3.1). I also travelled on other roads and around places where I halted for one or two days. I counted storks in wetlands too whenever I found them near to the survey routes. On a few occasions I travelled on foot, by bicycle, by train, by bus, and also by boat while crossing rivers and looked around river islands. While returning, the same routes were avoided as far as practicable and if the same routes were followed, the storks were not counted to avoid double count.

In addition to the roadside counts I went to some interior places in search of nesting colonies. Surveys were done on information from locals and where nesting habitat looked suitable. I also took help of some literature (Barooah, 1991; Saikia and
Fig. 3.1. Routes and major towns covered during the survey of the stork breeding-season in 1994-95.
Bhattacharjee, 1989a, b; Saikia and Bhattacharjee, 1990a, b) and my personal experience to find out the nesting colonies. I counted number of nest(s), number of young and adult stork(s) found on nests (for identification of young and adult, see chapter 5, section 5.3.3), listed separately and finally added to the total number of storks counted.

The range of the survey was from Assam-Bengal and Assam-Bangladesh borders in lower Assam up to Tinsukia in upper Assam. Out of the 23 districts of Assam, 18 districts lie in the Brahmaputra valley of which except Sonitpur 17 districts were covered. To cover a vast area, seven districts of Upper Assam were surveyed during January and early February 1995; while eight districts of Lower Assam were surveyed during February and March 1995. In the Central Assam, Morigaon district was covered in March 1995 and Nagaon district in November 1994 January and March 1995. Part of the data collected during November and December 1994 were from the eight Lower Assam districts.

3.2.2 Summer census during non-breeding season (1996)

Nine townships were selected for the summer census on the basis of past experiences and information (Fig. 2.4). These townships were situated both on the north and south bank of the river Brahmaputra and were well represented in the entire Brahmaputra valley. Eight major townships of Assam along with their surrounding areas were visited once in June; while Misamari was visited in July 1996. It was a random total count. The habitats of the storks were also noted.
Random visits to the breeding colonies were paid during 1995-96 and 1996-97 breeding season. On information from local, further sites were also visited in some parts of the valley to discover new colonies.

3.3 RESULTS

3.3.1 Population during breeding season (1994-95)

Of the 17 districts surveyed in the Brahmaputra valley, the Greater Adjutant Stork (GAS) was found in seven districts only (Table 3.1 and Fig. 3.2). A total of 573 GAS were counted during the survey of which 470 were counted in the field (field = wetland, crop field, marshy area, river bank and dry barren land where GAS were found to foraging or resting), and 103 were counted on nest. Out of total adults (432) counted, 411 adults were found in the field and 21 were found on the nest. Fifty nine young ones were seen in the field along with the adults, while 82 were seen on the nest. The ratio of the adult and juvenile was 3:1.

Greatest number of storks (374) was found in Kamrup district which represents 65% of the total population. While only three GAS was reported from North Lakhimpur district in November 1994 by Bibhab Kumar Talukdar and Anwaruddin Choudhury (pers. comm.); however I did not see GAS during my survey in North Lakhimpur district. In Morigaon district also, storks were found only in the nesting colony. Except in Nalbari and Kamrup district, juveniles were not found in the field, but barring Jorhat and North Lakhimpur district where I did not find nesting colony, young ones were found on nest in five districts.
Fig. 3.2. Distribution of the Greater Adjutant Stork in the Brahmaputra Valley, Assam, during the 1994-95 breeding season.
Table 3.1 Distribution of GAS in different districts of the Brahmaputra valley, Assam during the breeding season 1994-95.

<table>
<thead>
<tr>
<th>District</th>
<th>Number of Greater Adjutant Stork</th>
<th>Adult</th>
<th>Young</th>
<th>Adult</th>
<th>Young</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In Field</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Assam</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dhubri</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Kokrajhar</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bongaigaon</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Goalpara</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Barpeta</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nalbari</td>
<td>11</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Kamrup</td>
<td>295</td>
<td>56</td>
<td>5</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Darrang</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Central Assam</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morigaon</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Nagaon</td>
<td>65</td>
<td>0</td>
<td>4</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Upper Assam</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golaghat</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Jorhat</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sibsagar</td>
<td>32</td>
<td>0</td>
<td>7</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Dibrugarh</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Tinsukia</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Dhemaji</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>North Lakhimpur</td>
<td>3*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>411</strong></td>
<td><strong>59</strong></td>
<td><strong>21</strong></td>
<td><strong>82</strong></td>
<td></td>
</tr>
</tbody>
</table>

* Talukdar and Choudury (pers. comm.), see the text

Throughout the Brahmaputra valley, I counted 71 active nests in nine nesting colonies (see Chapter 4, section 4.4.1.4 for detail; also see section 3.4.1 for explanation), (Table 3.2, Fig. 3.3).
Fig. 3.3. Distribution of nesting colonies of the Greater Adjutant Stork in the Brahmaputra Valley, Assam during the 1994-95 breeding season.
Table 3.2 Number of GAS nests and nesting trees in selected nesting colonies in the Brahmaputra valley, Assam.

<table>
<thead>
<tr>
<th>District</th>
<th>Colony</th>
<th>1994 - 1995 Date</th>
<th>No. of Nest Tree</th>
<th>1995 - 1996 Date</th>
<th>No. of Nest Tree</th>
<th>1996 - 1997 Date</th>
<th>No. of Nest Tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nalbari</td>
<td>Daulasal</td>
<td>14 Feb 95</td>
<td>2</td>
<td>NV</td>
<td>NV</td>
<td>NV</td>
<td>NV</td>
</tr>
<tr>
<td>Kamrup</td>
<td>Singimari</td>
<td>5 Feb 95</td>
<td>2</td>
<td>9</td>
<td>NV</td>
<td>NV</td>
<td>NV</td>
</tr>
<tr>
<td></td>
<td>Dadara</td>
<td>5 Feb 95</td>
<td>3</td>
<td>8</td>
<td>26 Feb 96</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Satgaon</td>
<td>NV</td>
<td>27 Feb 96</td>
<td>2</td>
<td>7</td>
<td>3 Oct 96</td>
<td>2</td>
</tr>
<tr>
<td>Morigaon</td>
<td>Manaha</td>
<td>25 Mar 95</td>
<td>4</td>
<td>9</td>
<td>NV</td>
<td>NV</td>
<td>19 Oct 96</td>
</tr>
<tr>
<td>Nagaon</td>
<td>Haibargaon</td>
<td>28, 29, 31 Mar 95</td>
<td>7</td>
<td>18</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Khutikatia</td>
<td>31 Mar 95</td>
<td>1</td>
<td>5</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Barpujia</td>
<td>26 Mar 95</td>
<td>2</td>
<td>5</td>
<td>29 Dec 95</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>28 Feb 96</td>
<td>2</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sibsagar</td>
<td>Dichial</td>
<td>11, 13 Jan 95</td>
<td>4</td>
<td>6</td>
<td>NV</td>
<td>28 Nov 96</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Bagharchuk</td>
<td>12 Jan 95</td>
<td>4</td>
<td>8</td>
<td>NV</td>
<td>28 Nov 96</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6 Mar 97</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maganapar</td>
<td>NV</td>
<td>NV</td>
<td>6 Mar 97</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

NV: Colony not visited
*Intensive study was done

3.3.2. Population during non-breeding season (1996)

Four hundred forty GAS were counted out of which 145 (33%) were juveniles (Table 3.3). Greatest number of storks (200) were counted in Guwahati city; while smallest number (3) in Jorhat. During the breeding season 1994-95, I did not visit Tezpur and Misamari which are located in Sonitpur district. However, during the survey in non-breeding season, I counted 53 and 17 storks at Tezpur and Misamari respectively.
Table 3.3  Sighting of Greater Adjutant Storks in the Brahmaputra valley, Assam during non-breeding season (1996)

<table>
<thead>
<tr>
<th>Township</th>
<th>Adult</th>
<th>Juvenile</th>
<th>Total</th>
<th>Site</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dibrugarh</td>
<td>7</td>
<td>3</td>
<td>10</td>
<td>Near Slaughter house in marsh</td>
<td>I used to see at least 20 GAS in last 3 years. Local say population decreasing</td>
</tr>
<tr>
<td>Sibsagar</td>
<td>28</td>
<td>12</td>
<td>40</td>
<td>Near slaughter house, marsh</td>
<td>Two different flocks in two different sites</td>
</tr>
</tbody>
</table>
| Jorhat     | 2     | 1        | 3     | Garbage Centre                           | "Possible nesting site is Nimatighat (10 km) near the Brahmaputra."
| Tezpur     | 45    | 8        | 53    | Garbage and Burial ground near fish and meat market | Two different flocks                                                   |
| Misamari   | 17    | 0        | 17    | Army Butchery                            | "Nesting area not known, entire population vanishes in the breeding season. As many as 30 GAS can be seen."
| Nagaon     | 65    | 27       | 92    | Garbage dumps                            | Nesting colony is about three km away                                   |
| Guwahati   | 118   | 82       | 200   | Garbage dumps                            | Nesting colony is not near                                              |
| Rangia     | 7     | 2        | 9     | Army Butchery,                           | Fish market                                                             |
| Nalbari    | 6     | 10       | 16    | Near fish market                         | Local says population decreased                                         |
| Total      | 295   | 145      | 440   |                                           |                                                                         |
3.3.3. Additional nesting colonies

During the breeding season of 1996-97 I discovered two more nesting colonies. I visited Satgaon (Mandakata) in Kamrup district and Maganapara (Bikrampur) in Sibsagar district on 3 October 1996 and 6 March 1997 respectively (Table 3.2). I counted eight nests at Satgaon and two nests at Maganapara in different Kadam Mitragyna parvifolia trees. Random visit to the nesting colonies on different dates and years showed variation in the number of nests and nesting trees.

3.4. DISCUSSION

3.4.1. Population during breeding season (1994-95)

Due to their gregarious nature, the GAS were found to forage in flock in wetlands and marshy areas, in search of live prey during their breeding season in winter. Owing to their larger size and conspicuous foraging habit in compact flock, they could be easily spotted and separated from other storks even from a long distance. While surveying inundated paddy fields, marshy areas, wetlands and river banks I could locate most of the typical foraging areas of the GAS. However, when the routes ran through forest or thickly populated area, I could have missed a few storks. In comparison to the vast study area, road side count covered a narrow belt, however survey routes were spread in the flood plain zone of the valley (see chapter 2) where maximum foraging habitats were situated. Moreover, I thoroughly surveyed some of the wetlands and garbage dumps in major townships. The places where I halted for two to three days, I moved to some interior places which supplemented more area to the main road side count.

However, due to their high power of mobility and soaring ability, sometimes GAS might have had reached from a surveyed area to another area before I counted them there.
Because of this, a remote possibility of some double count might not be ruled out.

This survey depicts distribution and gives an idea of the present status of GAS in the Brahmaputra valley. Though GAS ranged from lower Assam to upper Assam, it seems that they were localised only in seven districts. Nesting colonies were found only in five districts; it is not known where the GAS of Jorhat and North Lakhimpur district breed. During their five year study (1989-94) of conservation of GAS, Bhattacharjee and Saikia (1996) also did not find nesting colonies in these two districts. However, they saw nesting colonies in Barpeta, Darrang and Golaghat district. The latter included Kaziranga national park which was out of my study area. The nesting colony discovered in Morigaon district was a new addition.

Though I saw GAS only in seven districts, Bhattacharjee and Saikia (1996) report GAS from 12 districts. I did not survey Sonitpur district and Kaziranga national park in Golaghat district which were surveyed by them. This difference in result could be because of different survey methods. I excluded the protected areas and did not repeat the same area surveyed already, while they surveyed thrice in a year for five years consecutively. However, in 31 March 1997 winter I saw a GAS with bright plumage roosting on a Simalu tree *Bombax ceiba* with 25 vultures at Fakiragram in Kokrajhar district which was not reported earlier. This suggests that there is a possibility of expansion of GAS distribution range and their actual population.

Saikia and Bhattacharjee (1989a) estimated 300 GAS in Assam in 1989. Rahmani et al. (1990) counted only 80 storks on 10 spots in five districts between 29 April and 9
May 1989 during their road side count. Prior to these no scientific information about the population of GAS was available. Lately, Bhattacharjee and Saikia (1996) reported that there were 649 GAS in the Brahmaputra valley in 1994 including all protected areas. They have shown that there was a population fluctuation in different districts over the years, the over-all number of breeding and non-breeding GAS in the valley increased by 6% and 14 % respectively between 1989 and 1994. Congeneric Marabou stork *Leptoptilos crumeniferus* has been increasing in eastern Africa greatly in numbers (Pomeroy, 1973; 1978c; 1986) from the early years of the 20th century.

Counting the storks only in the field would have given a smaller population size had I not counted the storks on nest. Nest counting has shown that out of 411 adults counted that during 1994-95 breeding season, at least 71 pairs GAS (34.55%) bred. During 1971-72 breeding season, 56-60% Marabous were found to breed in Uganda (Pomeroy, 1973). Though I did not count breeding and non-breeding storks separately in the field, number of nest clearly showed the minimum number of breeding pair in 1994-95. However, I should mention here that during the nesting colony analyses I referred that total number of nest was 65 (see chapter 4, section 4.4.1.4), because I considered the nesting colony survey period since 8 January to 31 March 1995, while in the population survey I added six more nests at Nagaon which I had seen in November 1994.

In upper and central Assam, I did not see young storks in the field, while in the lower Assam I counted 59 juveniles in the field. The reason could be due to the different
survey time in different regions of the valley. I surveyed central and upper Assam during the early part of the survey, when young GAS might have not yet fledged. Counting the storks on nest compensated this drawback. Fifty six juveniles found in Kamrup district alone could be because of the late survey in that area. However, one year old sub-adult might also consist of bulk of the young population.

Inter and intra-colony nesting asynchronisation is found in the GAS. Marabou breeding seasons also vary geographically (Pomeroy, 1978c). Therefore a random counting of nests during the survey only gives the minimum number of nests in the Brahmaputra Valley.

Discovery of additional nesting colonies in Kamrup and Sibsagar district during the breeding season of 1995-96 and 1996-97 reveals the fact that there is a possibility of more nesting colonies in the valley. These two nesting colonies were not new, but traditional. On the basis of this I believe that there might be some potential sites of GAS breeding which are yet to be explored.

3.4.2. Population during non-breeding season (1996)

Pomeroy (1978c) observed that Marabous show marked seasonal fluctuations in numbers wherever they occur. They probably undertake migrations of hundreds of kilometers (Pomeroy, 1978b). Similar behaviour pattern is also shown by GAS. It was supposed that in the early part of the 19th century, the breeding population of GAS in Mayanmar used to migrate to the eastern India during the non-breeding season.
(Humes and Oates, 1890). Although ringing data are not available, during my three years study, I observed that in summer, after the completion of breeding, the GAS along with newly fledged juveniles used to move to regular feeding grounds in urban and semi-urban area (see also chapter 2). These regular feeding grounds are characterised by garbage dumping grounds, areas near slaughter houses, and fish and meat markets. In the non-breeding season, the GAS also feeds on food obtained as a consequence of human activities. Similar behaviour was seen in Marabou Storks in Africa (Pomeroy, 1973). Similar feeding grounds are found in some major townships of Assam. Therefore, a summer census in such places was justified where both adults, sub-adults and newly fledged juveniles were seen together.

Andrewartha and Birch (1954) suggested that the whole population of animals can be regarded as the sum of a number of local populations. I considered number of GAS in each township as local population and summing up the numbers of GAS in nine townships would give the approximate total population of GAS in the valley. However, some townships had more than one site. All the townships were well apart and there was little chance that GAS moved from one site to another. Due to their strong site fidelity, it appears that the same local population of a township used to forage in the same township regularly. However, movement from one site to another nearby site within one township was possible. But the possibility of double count was very less as I covered all sites of a township within a short period of time on the same day.

The total population found in the summer census in 1996 is less than the population found during the breeding season of 1994-95. However, it does not necessarily imply that the population of GAS declined in subsequent years. Bhattacharjee and Saikia
(1996) recorded year wise population variation from place to place. Annual variation in the Marabou stork population is also seen (Pomeroy, 1977b). I visited some of the nesting colonies (Table 3.2) in 1995-96 and 1996-97 breeding seasons and found different number of nests and nesting trees. Even in the same season, the number of nests changed. Therefore counting the maximum number of nests in each colony through regular monitoring is important to know the breeding population of a particular breeding season.

In the same way, population in every township might differ during different days and even in the different hours of the day. I studied flock behaviour of GAS in Nagaon and Guwahati during the non-breeding season, ten days on each site and observed that the number of GAS was different on different days and hours of a day (see chapter 6, section 6.5.1). Therefore, as summer census was a random one, the total number of storks counted in 1996 was a minimum estimate of GAS population in the Brahmaputra valley. I had selected only nine townships throughout the valley, on the basis of 1994-95 winter survey, available literature, local information and my personal experience. There could have been more townships with GAS, but as all the prior information was consulted, it seems I had covered almost all the known areas of GAS.

Greatest number of storks were counted in Kamrup district, during both winter and summer census. Main bulk of the GAS in Kamrup district was found in Guwahati city. This is because in Guwahati there is a huge garbage dumping ground where all the city refuses are dumped regularly. There are fish and meat markets and slaughter houses from where inedible animal parts are thrown away everyday. These sites harbour many
scavengers including GAS. During the breeding season also, some non-breeding GAS are found on these sites. Therefore, during the late survey in 1994-95 breeding season, the maximum number GAS were found in Guwahati city.

Though during the non-breeding season, the GAS scavenge in urban area, in early monsoon when low lying areas are inundated, they disperse in search of live prey.

Moreover, it is supposed that both adults and newly fledged juveniles from breeding colony will return to the summer foraging ground, it seems that some of them disperse elsewhere. During 1995-96 breeding season 50 juveniles fledged from the breeding colonies at Nagaon, but after frequent visit to the summer foraging ground near to the colonies where all GAS of Nagaon are believed to assemble in summer, not more than 35 juveniles were seen. A good number of GAS were seen at Tezpur and Misamari, but their breeding colonies are not known. In the last week of February 1996, 43 GAS were seen in Donga beel in Kaziranga National Park (Pankaj Sarma, pers. comm.).

These suggest that a road side survey including all breeding colonies during breeding and subsequent township census during non-breeding season within a brief period are useful to count the number of GAS. Survey during the breeding season will give an account of minimum breeding pair and subsequent survey in the summer will show how many new GAS are added to the population. However, regular monitoring and taking the average number in the summer foraging grounds would be better as done in Marabou stork (Pomeroy, 1973; 1975). To know the local migration from breeding
ground to the summer foraging ground and to explore new breeding colonies, ringing of GAS would be beneficial. In short, on the basis of two censuses, it can be estimated that in 1996 not less than 600 GAS were present in the Brahmaputra valley, Assam.
Chapter 4

NESTING ECOLOGY
CHAPTER 4

NESTING ECOLOGY

4.1 INTRODUCTION

Birds build nests to protect themselves, their eggs, and their young from predators and from adverse weather (Gill, 1990). Nests have four primary functions: safety from predators, provide micro-climate suitable for incubation, serve as a cradle for dependent young until they fledge, and roosting chamber for adults while attending eggs or young. Nest placement in or out of the sun, shade, or wind has a major effect on the nest micro-climate and a pair’s breeding success.

The environmental conditions in the nest will be affected by the nest architecture, its exposure to the winds, protection from storms and insulation (Alejandro et al., 1994). The selection of an appropriate nest site is vital to the reproduction of birds because it determines the environment to which adults, eggs, and chicks will be exposed during critical periods. In general, both nest site selection and construction should provide necessary protection against predation of eggs and nestlings. Nest site characteristics may be influenced by the nest site (characteristics within immediate vicinity of the nest) and the nest patch (characteristics of the habitat patch surrounding the nest) (Burger and Gochfeld, 1985). Nest site selection in birds involves the choice of a particular location among the available habitats and sites (Patridge, 1978). It is closely tied to fitness because of the effects on offspring production (Martin and Roper, 1988). Nesting ecology of birds deals with the interactions between birds activities and their biotic and abiotic components available in the nest site and nest patch.

Recent studies have shown that colonial nesting is adaptive where food sources are unevenly distributed; whereas solitary nesting is favoured where the food supply is stable and uniformly distributed (Horn, 1968). About 13% of all the birds in the world are colonial nesters (Lack, 1967). Colony is an aggregation of breeding birds characterised by two or more individuals nesting close to each other, generally feeding outside the nesting area and organised into various types of social stimulation and elements of flock behaviour and other features (Crook, 1965; Gotmark and Anderson, 1984). In colonial species, colony, general habitat and
territory selection are not necessarily made at the same time, nor even by the same member of the pair (Burger, 1985). They select their habitat and nest sites according to environmental and social factors (Burger and Gochfeld, 1981). For many species, the process of nest site selection involves: (1) habitat selection, (2) choosing a part of this habitat on the basis of particular physical factors, (3) defining territorial boundaries and (4) selecting the nest site. Coloniality affords easier location of food items through cooperative food searching or interspecific learning of feeding areas (Ward and Zahavi, 1978).

There are two types of colony: single species colony and mixed species colony of two or more than two species of birds of together in the same habitat. Many workers have studied nesting ecology, nest site selection in single species colony (Burger, 1974; Burger and Gochfeld, 1981, 1990; Crabtree et al., 1989; Ebert and Picman, 1993; Flemming et al., 1992; Ogden and Hornocker, 1977; and Wood et al., 1989) as well as in mixed colony (Alejandra et al., 1994; Beaver et al., 1980; Burger, 1979; Fasola and Alieri, 1992; Gloutney and Clark, 1997; Norment, 1993; Post, 1990; Thompson, 1981; and Willms and Crawford, 1989).

Many species of water birds of the order Ciconiiformes are colonial. Out of the 20 species of storks (ciconiidae family) found in the world, ten are colonial nester (see Kahl, 1987). However, except some studies (Ruckdeschel and Shoop, 1987; Rodgers et al., 1996) specific study on nesting habitat of colonial storks are comparatively limited. Out of six breeding species found in India (Kahl, 1971), four species are colonial nester: Asian Openbill Anasomus oscitans, Painted Stork Mycteria leucocephala, Lesser Adjutant Stork Leptoptilos javanicus, and Greater adjutant stork Leptoptilos dubius. Some work, particularly on the nesting ecology of these colonial storks have been done (Desai, 1971; Datta and Pal, 1993; Saikia and Bhattacharjee, 1990a, b; and Urfi, 1989). More recently, except few studies (Bhattacharjee and Saikia, 1996; Saikia and Bhattacharjee, 1995, 1996a, b), detail study on the nesting ecology of Greater Adjutant Stork (GAS) has not been done.

I studied nesting ecology of GAS during 1995-1997 in the Brahmaputra valley, Assam including two years intensive study at two adjacent nesting colonies at Nagaon, in the
central Assam. This study includes vegetation structure and other habitat parameters in relation to the nest building. In this chapter, a detail account of the nesting ecology of GAS is presented.

4.2 METHODS

4.2.1 Throughout Assam

A survey of nesting colonies was done from 8 January through 31 March, 1995 in the Brahmaputra valley, Assam. The survey routes and duration were the same as in the population survey and were outside the protected forest area (see Chapter 3, section 3.2). In addition to following the national highways and public roads, I searched for nesting colonies in villages and forests near the survey route. Besides discovering the colonies myself, information about the location of the colonies were collected from local people, literature (Barooah, 1991; Saikia and Bhattacharjee, 1989; 1990a,b) and my personal experience.

I identified the nesting trees and counted number of nest(s) on each of them. I measured the tree architecture which includes height of the tree from the ground, diameter at breast height (DBH) and canopy spread. Height of the tree and height of the nest were estimated visually after several exercises on known height of some poles. Canopy spread was measured by the formula: $\pi r^2$; where $r =$ mean radius of the approximate circular canopy spread. Considering the tree trunk at the centre of the circle the branch tips extending parallel to the ground towards the circumference were assumed radii. The 'r' was calculated by summing the distances of the outer most tree branch tip in four diagonal directions and dividing the total distance by four.

Within a radius of 10m, I identified, counted and measured the tree architecture of the non-nesting trees which were ≥ 10 m in height and had side branches by the same method applied for nesting trees.

The ground cover (shrubs or grass) below each nesting tree was measured in five categories: 0%, ≤ 25%, ≤50%, ≤75% and ≤100%. The dominant vegetation around the 25 m radius of each nesting tree was recorded. The nearest nesting tree distance (NNTD) was also measured from each nesting tree.
The distance of other habitat parameters—nearest house, nearest forest, nearest road, nearest water source and nearest foraging ground from the nesting tree was measured. I considered nearest forest either as a thick mixed plantation, generally found in the village, or natural patch of thick vegetation. The nearest water source could be river, wetland (beel) and a marshy area. The nearest foraging ground was either a garbage dump, or a wetlands or a marshy area including inundated paddy field where GAS were usually found to forage. For the last two parameters, i.e., water source and foraging ground, apart from measuring the distance myself, sometimes I took help of the local when I could not locate them.

In addition to these, I also noted down the general description of each nesting colony; particularly about their physiography and interviewed local people.

4.2.2 Intensive Study
After the completion of nesting survey, I selected Nagaon for the intensive study due to large number of nests and nesting trees were found (see the result). There were two adjacent nesting colonies—North Haibargaon, and Khutikatia (see Chapter 2, section 2.6).

The method of measuring the tree architecture and NNTD were same as it was done in the study of nesting ecology throughout Assam. But here, the non-nesting trees (≥ 10 m in height) were measured within the 25 m around each nesting tree. The distance of nearest house was measured. Nests were monitored daily and only the highest number of nest(s) contained by each tree during the respective breeding season were considered for the analysis. Instead of measuring the height of the nest, I recorded the nest placement in the upper, middle or lower canopy.

At Haibargaon nesting colony, I did a vegetation sampling (≥ 10 m high trees) in two randomly selected 100 sq. m area to know the tree species availability in the habitat.

4.3 Hypotheses and Analyses
Hypothesis 1: Nesting trees are different from non-nesting trees with respect to the tree architecture and they are different in different colonies throughout Assam. The
relative nest height (nest height / tree height) is different in different nesting colonies. The architecture of nesting trees having larger number of nests are different with that of other nesting trees having lesser number of nest.

Unpaired t-test was performed for height, DBH and canopy spread separately for the data of throughout Assam and Nagaon. For the data of Nagaon, I first analysed the data of each year separately and then pooled the data of two years together. The common non-nesting trees were included for one nesting tree only to avoid double counting. One-way ANOVA was done between each variable of tree architecture in different colonies. The mean height of the nests per tree was divided by the respective tree height to get the relative nest height, and then a non-parametric Kruskal-Wallis test was done. I categorised trees with larger number of nest on which there were ≥ 5 nests. A t-test was done between the architecture of two categories of trees.

Hypothesis 2: There is an association between the number of nest and tree architecture and habitat parameters.

Pearson correlation test was done separately for the data collected throughout Assam and at Nagaon. As there was no significant difference among the variables in two years at Nagaon (see result), I pooled the data of two years together for the test. Principal component analysis (PCA) was performed among five habitat parameters and only two components were retained as principal components because the eigenvalues less than one in rest of the three components (Kachigan, 1986).

Hypothesis 3: GAS show preferenc to particular tree species for nesting available in the colony.

I analysed nesting tree species preferred or avoided from the total number of trees used for nesting following ‘analysis of utilization-availability data’ (Neu et al., 1974; Byers and Steinhorst, 1984). I calculated relative availability of nesting tree species by dividing number of trees of each particular species by total number of nesting tree
counted. The observed usage was the total number of nest counted per species. At Nagaon, I pooled two years' of data together and analysed.

All the analyses were done on STATA 5.0 program (stata corp., 1993) and PREFER program (Prasad and Gupta, 1992).

4.4 RESULTS

4.4.1 Nesting Colonies Throughout Assam

Seventeen out of 18 districts in the Brahmaputra valley were covered during the nesting colony survey. I found nine nesting colonies in five districts (Table 4.1a). I counted 65 active nests on 29 nesting trees.

4.3.1.1 Location and general description

The colonies were distributed in the western, middle and eastern Assam on both the bank of Brahmaputra river (Fig. 4.1). Except one nesting colony at Bagharchuk in Sibsagar district, all the nesting colonies were found in the villages and semi-urban area. The Bagharchuk colony was in a riverine forest on the bank of Dikhow river, a tributary of the Brahmaputra, which separates it from the Bhotiapar village. In 1996 and 1997, I visited two other nesting colonies named Mandakata and Bikrampur in Kamrup and Sibsagar district respectively; which were also located in village. (However, they are not included here for analysis).

The characteristic feature of villages in Assam is that they are rich in thick vegetation cover. All the colonies were at the vicinity of human settlements (Table 4.1b) and they were very close to public roads. Some colonies were even intersected by public roads. Another uniqueness of the village scenario in Assam is that almost every Assamese has either private forest or mixed plantation including bamboo near his house. Five of the nine colonies were within this kind of forest and rests were also very near to the forest (Table 4.1b). Nearest water source from nesting colony was as close as 26 m and as far as five km; while nearest foraging ground was found between one to seven km from the nesting colony (Table 4.1b).
Table 4.1a Nest number and nesting tree architecture of Greater Adjutant Storks in different colonies and districts throughout the Brahmaputra valley, Assam during 1994-95 breeding season

<table>
<thead>
<tr>
<th>District</th>
<th>Colony</th>
<th>No. of Tree</th>
<th>No. of Nest</th>
<th>Height of tree (m) ± SD</th>
<th>Height of nest (m) ± SD</th>
<th>DBH (m) ± SD</th>
<th>Canopy spread (sq. m) ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nagaon</td>
<td>Haibargaon</td>
<td>7</td>
<td>14</td>
<td>20.29±1.25</td>
<td>19.79±1.38</td>
<td>0.67±0.20</td>
<td>147.34±60.91</td>
</tr>
<tr>
<td></td>
<td>Khutikatia</td>
<td>1</td>
<td>3</td>
<td>25</td>
<td>25</td>
<td>1.32</td>
<td>352.32</td>
</tr>
<tr>
<td></td>
<td>Barpujia</td>
<td>2</td>
<td>5</td>
<td>21.5±2.12</td>
<td>21.5±2.12</td>
<td>4.18±0.62</td>
<td>884.06±510.94</td>
</tr>
<tr>
<td>Sibsagar</td>
<td>Dichial</td>
<td>4</td>
<td>6</td>
<td>27.5±2.08</td>
<td>27.38±1.89</td>
<td>0.62±0.06</td>
<td>90.16±47.86</td>
</tr>
<tr>
<td></td>
<td>Bagharchuk</td>
<td>4</td>
<td>8</td>
<td>29.5±2.38</td>
<td>29±2.71</td>
<td>0.72±0.08</td>
<td>85.23±68.89</td>
</tr>
<tr>
<td>Kamrup</td>
<td>Singimari</td>
<td>2</td>
<td>9</td>
<td>23±7.07</td>
<td>22.5±7.78</td>
<td>1.02±0.68</td>
<td>156.25±98.51</td>
</tr>
<tr>
<td></td>
<td>Dadara</td>
<td>3</td>
<td>8</td>
<td>21.33±0.58</td>
<td>21.33±0.58</td>
<td>0.61±0.06</td>
<td>96.08±38.28</td>
</tr>
<tr>
<td>Nalbari</td>
<td>Daulasal</td>
<td>2</td>
<td>3</td>
<td>17.5±2.12</td>
<td>17.25±1.77</td>
<td>0.62±0.01</td>
<td>113.75±8.88</td>
</tr>
<tr>
<td>Morigaon</td>
<td>Manaha</td>
<td>4</td>
<td>9</td>
<td>20</td>
<td>19.88±0.25</td>
<td>0.71±0.16</td>
<td>152.89±80.71</td>
</tr>
</tbody>
</table>
Table 4.1b Habitat parameters of Greater Adjutant Storks nesting colonies in different places and districts in the Brahmaputra valley, Assam during 1994-95 breeding season.

<table>
<thead>
<tr>
<th>District</th>
<th>Colony</th>
<th>NNTD* (m) ± SD</th>
<th>Nearest house (m) ± SD</th>
<th>Nearest road (m) ± SD</th>
<th>Nearest forest (m) ± SD</th>
<th>Nearest water (m) ± SD</th>
<th>Nearest forest (m) ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nagaon</td>
<td>Haibargaon</td>
<td>57.86±36.04</td>
<td>18.29±5.77</td>
<td>40.14±37.35</td>
<td>14.29±37.80</td>
<td>249.29±84.68</td>
<td>3000</td>
</tr>
<tr>
<td></td>
<td>Khutikatia</td>
<td>3000</td>
<td>40</td>
<td>100</td>
<td>0</td>
<td>300</td>
<td>4000</td>
</tr>
<tr>
<td></td>
<td>Barpujia</td>
<td>15</td>
<td>35</td>
<td>12</td>
<td>20</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>Sibsagar</td>
<td>Dichial</td>
<td>300±141.42</td>
<td>110±81.55</td>
<td>81.25±55.43</td>
<td>5±10</td>
<td>185±157.80</td>
<td>2000</td>
</tr>
<tr>
<td></td>
<td>Bagharchuk</td>
<td>31.5±45.68</td>
<td>100</td>
<td>90</td>
<td>0</td>
<td>26.25±2.5</td>
<td>3000</td>
</tr>
<tr>
<td>Kamrup</td>
<td>Singimari</td>
<td>100</td>
<td>25±21.21</td>
<td>60</td>
<td>0</td>
<td>3000</td>
<td>7000</td>
</tr>
<tr>
<td></td>
<td>Dadara</td>
<td>8.67±1.15</td>
<td>20</td>
<td>40</td>
<td>0</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>Nalbari</td>
<td>Daulasal</td>
<td>600</td>
<td>22.5±0.71</td>
<td>70</td>
<td>0</td>
<td>400</td>
<td>4000</td>
</tr>
<tr>
<td></td>
<td>Manaha</td>
<td>8.38±2.93</td>
<td>23.75±2.5</td>
<td>100</td>
<td>0</td>
<td>1000</td>
<td>3000</td>
</tr>
</tbody>
</table>

* NNTD = Nearest Nesting Tree Distance
According to the local information all colonies were traditional and some of them were more than 50 years old. I did not find nests of other birds on the same tree used by GAS except in one case at Dichial in Sibsagar district. I saw a solitary nest of GAS on a Urium tree *Bischofia javanica* where seven abandoned nests of Openbill Stork *Anastomus oscitans* were present. In October, 1993 I had seen one GAS nest on the same tree surrounded by ten active Openbill Stork nests. However, I saw Spottedbilled Pelican *Pelecanus philippensis* and Openbill Stork roosting together on the nesting trees of GAS at Bagharchuk colony.

### 4.4.1.2 Habitat Relationships

Mean distances of habitat parameters from each nesting tree are shown in Table 4.2. Fifty five percent nearest nesting tree distance (NNTD) was ≤ 25 m. The largest NNTD being three km was due to a single nesting tree in Khutikatia nesting colony from which the nearest nesting tree of Haibargaon nesting colony was three km away. Sixty two percent nesting trees were within 25 m from a nearest house. Forty one percent nesting trees were ≤ 100 m from nearest road. Eighty six percent nesting trees were found in the forest i.e., within thick vegetation; 44% and only 17% nesting trees were within 500 m and five km respectively from nearest water source. Fifty one percent nesting trees were within three km from nearest foraging ground; while seven percent nesting trees were as far away as 7 km away from the foraging ground.

The dominant vegetation around each nesting tree was bamboo (79%) (Table 4.3). Below most of the nesting trees ≤100% ground cover was found (Fig. 4.2). Only one Kadam tree *Mitragyna parvifolia* in Nagaon nesting colony was found in open place below which there was no ground cover.
Fig. 4.1  Ground vegetation cover below the nesting trees in all colonies throughout the Brahmaputra Valley, Assam (1994-95) and at Nagaon (1995-96, 1996-97)

Assam  
(n=29)

Nagaon  
(n=38)
Table 4.2 Habitat parameters of all nesting colonies of Greater Adjutant Storks in the Brahmaputra valley, Assam during the breeding season (1994-95)

<table>
<thead>
<tr>
<th>Habitat parameters</th>
<th>Mean Distance (m) ± SD (n=20)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>NNTD</td>
<td>214.5 ± 562.78</td>
<td>6.4 — 3000</td>
</tr>
<tr>
<td>Nearest house</td>
<td>45.79 ± 46.41</td>
<td>10 — 200</td>
</tr>
<tr>
<td>Nearest road</td>
<td>64.48 ± 37.41</td>
<td>1 — 150</td>
</tr>
<tr>
<td>Nearest forest</td>
<td>5.52 ± 19.20</td>
<td>0 — 100</td>
</tr>
<tr>
<td>Nearest water source</td>
<td>1023.79 ± 1560.75</td>
<td>25 — 5000</td>
</tr>
<tr>
<td>Nearest foraging ground</td>
<td>3310.35 ± 1416.82</td>
<td>1000 — 7000</td>
</tr>
</tbody>
</table>

NNTD: Nearest nesting tree distance

Table 4.3 Dominant vegetation around the nesting trees (n = 29) in the Brahmaputra valley, Assam during 1994-95 breeding season

<table>
<thead>
<tr>
<th>Dominant plants</th>
<th>Occurrence Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Bambusa</em> spp. and <em>Dendrocalamus</em> spp.</td>
<td>79.31</td>
</tr>
<tr>
<td><em>Tragia involucrata</em></td>
<td>10.34</td>
</tr>
<tr>
<td><em>Areca catechu</em></td>
<td>3.45</td>
</tr>
<tr>
<td><em>Cida cordifolia</em></td>
<td>3.45</td>
</tr>
</tbody>
</table>

4.4.1.3 Nesting and non-nesting trees

Twenty nine nesting trees and 46 non-nesting trees around the nesting trees were counted. The tree architecture (height, DBH and canopy spread) of the nesting trees differed with those of the non-nesting trees (Table 4.4). Height (t=4.61, df=73, p<0.001), DBH (t=3.83, df=73, p<0.001) and canopy spread
Table 4.4 Tree architecture of nesting and non-nesting trees (> 10 m in height, within 10 m radius around each respective nesting tree) in the Brahmaputra valley, Assam during 1994-95 breeding season

<table>
<thead>
<tr>
<th>Tree architecture</th>
<th>NESTING TREE (n=29)</th>
<th>NON-NESTING TREES (n=46)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Range</td>
</tr>
<tr>
<td>Height (m)</td>
<td>22.86 ± 4.28</td>
<td>16 - 33</td>
</tr>
<tr>
<td>Diameter at breast height (DBH) (m)</td>
<td>0.96 ± 0.93</td>
<td>0.34 - 4.62</td>
</tr>
<tr>
<td>Canopy spread (sq. m)</td>
<td>182.52 ± 228.91</td>
<td>28.27 - 1245.35</td>
</tr>
</tbody>
</table>

(t=2.37, df=73, p<0.02) of nesting trees were significantly greater than those of non-nesting trees. There were eight species of nesting trees (Table 4.5). The devil tree *Alstonia scholaris* (27.5%) and kadam *Mitragyna parvifolia* (20.7%) were more frequently used trees for nesting. Next to the solitary *Bischofia javanica*, *Alstonia scholaris* was the tallest tree. Twenty species of non-nesting tree were counted out of which soura *Streblus aspera* (30%) were more frequently encountered (Appendix 4.1).

Table 4.5 Number of trees of different species and number of nest(s) on them of Greater Adjutant Storks in the Brahmaputra valley, Assam during the breeding season 1994-95

<table>
<thead>
<tr>
<th>Tree species</th>
<th>No. of Trees</th>
<th>No. of Nest</th>
<th>Height (m) ± SD</th>
<th>DBH (m) ± SD</th>
<th>Canopy spread (sq. m) ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albizzia lucida</td>
<td>3</td>
<td>6</td>
<td>19.67 ± 1.15</td>
<td>0.51 ± 0.15</td>
<td>107.84 ± 34.72</td>
</tr>
<tr>
<td>Alstonia scholaris</td>
<td>8</td>
<td>16</td>
<td>26.25 ± 3.28</td>
<td>0.69 ± 0.08</td>
<td>86.05 ± 47.10</td>
</tr>
<tr>
<td>Bischofia javanica</td>
<td>1</td>
<td>1</td>
<td>28</td>
<td>0.57</td>
<td>74.81</td>
</tr>
<tr>
<td>Bombax ceiba</td>
<td>4</td>
<td>13</td>
<td>26 ± 6.27</td>
<td>1.05 ± 0.44</td>
<td>212.17 ± 110.16</td>
</tr>
<tr>
<td>Ficus benghalensis</td>
<td>2</td>
<td>5</td>
<td>21.5 ± 2.12</td>
<td>4.18 ± 0.62</td>
<td>884.06 ± 510.94</td>
</tr>
<tr>
<td>Ficus glomerata</td>
<td>1</td>
<td>2</td>
<td>21</td>
<td>0.94</td>
<td>216.95</td>
</tr>
<tr>
<td>Mitragyna parvifolia</td>
<td>6</td>
<td>13</td>
<td>19.67 ± 2.16</td>
<td>0.64 ± 0.08</td>
<td>86.05 ± 47.10</td>
</tr>
<tr>
<td>Trewia nudiflora</td>
<td>4</td>
<td>9</td>
<td>20</td>
<td>0.71 ± 0.16</td>
<td>152.89 ± 80.71</td>
</tr>
</tbody>
</table>

Except DBH and canopy spread of non-nesting trees the tree architecture of nesting as well as non-nesting trees of different species and in different colonies were significantly different. (Table 4.6).
Table 4.6 One-way ANOVA of tree architecture (a) among different species and (b) in different colonies of Greater Adjutant Storks in the Brahmaputra valley, Assam (1994-95)

<table>
<thead>
<tr>
<th>Tree architecture</th>
<th>NESTING TREE df=7, 21</th>
<th>NON-NESTING TREE df=19, 26</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>P</td>
</tr>
<tr>
<td>(a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>3.88</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>DBH</td>
<td>59.43</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Canopy spread</td>
<td>9.46</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>(b)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>10.45</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>DBH</td>
<td>47.56</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Canopy spread</td>
<td>8.39</td>
<td>p&lt;0.001</td>
</tr>
</tbody>
</table>

4.4.1.4 Nest

Sixty five active nests were counted throughout the Brahmaputra valley. Highest number of nest was counted in Nagaon district (Table 4.1a). As many as eight nests counted on a simalu Bombax ceiba tree at Singimari nesting colony in Kamrup district was greatest number of nest recorded on a single tree. The relative height of the nests in different colonies was not significantly different (Kruskal-Wallis $\chi^2=4.385$, df=8, p>0.82).

No correlation was observed between the number of nests and the tree architecture as well as between number of nests and habitat parameter (Table 4.7). Only a weak correlation was seen with the nearest foraging ground.

Table 4.7 Correlation of nest number with tree architecture and habitat parameters in the Brahmaputra valley, Assam during 1994-95 breeding season of Greater Adjutant Stork

<table>
<thead>
<tr>
<th></th>
<th>Height</th>
<th>DBH</th>
<th>Canopy spread</th>
<th>NNTD</th>
<th>Nearest house</th>
<th>Nearest forest</th>
<th>Nearest road</th>
<th>Nearest water source</th>
<th>NFG</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$</td>
<td>0.13</td>
<td>0.24</td>
<td>0.05</td>
<td>0.05</td>
<td>-0.19</td>
<td>-0.12</td>
<td>-0.14</td>
<td>0.29</td>
<td>0.37</td>
</tr>
<tr>
<td>$p$</td>
<td>0.49</td>
<td>0.22</td>
<td>0.80</td>
<td>0.82</td>
<td>0.32</td>
<td>0.53</td>
<td>0.48</td>
<td>0.13</td>
<td>0.05</td>
</tr>
</tbody>
</table>

NNTD: Nearest nesting tree distance, NFG = Nearest Foraging Ground

n = 29
4.4.1.5 Principal Component Analysis (PCA)

PCA extracted two components with eigen value greater than 1. The first component (PC I) explained 41.52% of variance and the second component (PC II) explained 33.56% (Table 4.8). The first two components cumulatively explained 75% of total variance. Except nearest house and nearest road, remaining three variables were positively correlated. However, all variables showed only moderate correlation. The second component (PC II) accounted for an additional 33.56% of the total variance. All correlation were positive, except for the nearest forest.

Table 4.8 Principal component analysis of five habitat parameters for the nesting ecology of Greater Adjutant Stork in the Brahmaputra valley, Assam during (1994-95) breeding season

<table>
<thead>
<tr>
<th>Variables</th>
<th>Principal Components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PC I</td>
</tr>
<tr>
<td>Nearest house</td>
<td>-0.54</td>
</tr>
<tr>
<td>Nearest road</td>
<td>-0.43</td>
</tr>
<tr>
<td>Nearest forest</td>
<td>0.10</td>
</tr>
<tr>
<td>Nearest water source</td>
<td>0.53</td>
</tr>
<tr>
<td>Nearest foraging ground</td>
<td>0.48</td>
</tr>
<tr>
<td>Percentage of total variance</td>
<td>41.52</td>
</tr>
<tr>
<td>Cumulative percentage</td>
<td>41.52</td>
</tr>
</tbody>
</table>

4.4.2 INTENSIVE STUDY

4.4.2.1 Nesting and Non-nesting trees

Twenty individuals of 10 species and 18 individuals of eight tree species were used by GAS for nesting in 1995-96 and 1996-97 breeding season respectively (Table 4.9). Helos Barringtonia acutangula and gahera Premna benghalensis were not used in 1996-97. The latter species at Haibaraon colony was felled in 1996 before the start of breeding. In the second nesting season (1996-97) some individual trees which were used for nesting in the first nesting season (1995-96) were reused, some were not used and some new trees were used. In the first nesting season (1995-96), a remarkable 35% Moj Albizia lucida was used; but it declined down to 16.67% in the next season. However, one moj tree was
felled at Haibargaon in 1996 which had one nest in the previous year. On the other hand, some nesting trees were consistently used in both year of my study.

Different tree species were of different tree architecture (Table 4.10). *Bombax ceiba* found to be the largest and *Barringtonia acutangula*, *Dowa Artocarpus lakoocha* and *thekera Garcinia cowa* were the small.

Table 4.9 Trees used for nesting and number of nest(s) on them in two successive breeding seasons at Nagaon

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># of Trees (%)</td>
<td># of Nest(s) (%)</td>
</tr>
<tr>
<td>Albizzia lucida</td>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td>Alstonia scholaris</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Artocarpus heterophyllus</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Artocarpus lakoocha</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Barringtonia acutangula</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Bombax ceiba</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Ficus glomerata</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Garcinia cowa</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Mitragyna parvifolia</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>Premna benghalensis</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

* The tree was felled in 1996, before the breeding season started

Table 4.10 Tree architecture of different nesting tree species in two successive breeding seasons of Greater Adjutant Stork (1995 - 96, 1996 - 97 combined together) at Nagaon

<table>
<thead>
<tr>
<th>Tree species</th>
<th>Height (m) ± SD</th>
<th>DBH (m) ± SD</th>
<th>Canopy spread (m) ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albizzia lucida</td>
<td>20.5±1.78</td>
<td>0.51±0.20</td>
<td>157.07±80.78</td>
</tr>
<tr>
<td>Alstonia scholaris</td>
<td>22.8±0.45</td>
<td>0.71±0.12</td>
<td>122.67±46.79</td>
</tr>
<tr>
<td>Artocarpus heterophyllus*</td>
<td>20</td>
<td>0.57±0.07</td>
<td>16±2.97</td>
</tr>
<tr>
<td>Artocarpus lakoocha*</td>
<td>18.33±0.58</td>
<td>0.43±0.20</td>
<td>82.93±63.41</td>
</tr>
<tr>
<td>Barringtonia acutangula</td>
<td>18</td>
<td>0.50</td>
<td>92.46</td>
</tr>
<tr>
<td>Bombax ceiba**</td>
<td>25</td>
<td>1.32</td>
<td>352.32</td>
</tr>
<tr>
<td>Ficus glomerata</td>
<td>20.75±0.87</td>
<td>0.99±0.64</td>
<td>209.32±8.81</td>
</tr>
<tr>
<td>Garcinia cowa*</td>
<td>18±1.73</td>
<td>0.33±0.05</td>
<td>73.31±60.04</td>
</tr>
<tr>
<td>Mitragyna parvifolia</td>
<td>19.67±0.82</td>
<td>0.59±0.12</td>
<td>123.56±68.18</td>
</tr>
<tr>
<td>Premna benghalensis</td>
<td>19</td>
<td>0.64</td>
<td>171.1</td>
</tr>
</tbody>
</table>

* Avoided, ** Preferred (Refer Table 4.14)
I counted 27 species of non-nesting trees (>10 m tall) within 25 m radius around nesting trees. In the whole nesting colony, cumulatively in both seasons there were 77 trees (Appendix 4.2). Jackfruit *Artocarpus heterophyllus* (14%), followed by *Albizia lucida* (13%) and Sonaru *Cassia fistula* (8%) were more frequently encountered.

The tree architecture of nesting and non-nesting tree as well as distance to the nearest house (*t* = -1.4823, *df* = 36, *p* > 0.1470) and NNTD (*t* = 0.9989, *df* = 36, *p* > 0.3245) between the two successive nesting seasons did not differ significantly (Table 4.11). However, their range varied slightly in two years due to the change of nesting trees. But the range of non-nesting tree architecture remained same.

Table 4.11 Results of *t*-test of tree architecture variables, nearest house and NNTD between 1995 - 96 and 1996 - 97 breeding season at Nagaon

<table>
<thead>
<tr>
<th>Tree architecture</th>
<th>Nesting Tree (df=36)</th>
<th>Non-Nesting Tree (df=115)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>t</em></td>
<td><em>p&gt;</em></td>
</tr>
<tr>
<td>Height</td>
<td>0.0124</td>
<td>0.9902</td>
</tr>
<tr>
<td>DBH</td>
<td>0.6093</td>
<td>0.5462</td>
</tr>
<tr>
<td>Canopy spread</td>
<td>1.2794</td>
<td>0.2089</td>
</tr>
</tbody>
</table>

As nesting and non-nesting tree architecture did not differ in two years, I pooled the data together and found that nesting and non-nesting trees differed significantly in height (*t*=7.9431, *df*=153, *p*<0.0001), DBH (*t*=3.7581, *df*= 153, *p*<0.001) and canopy spread (*t*=5.0359, *df*=153, *p*<0.001).

The tree architecture of nesting non-nesting trees among different species different significantly (Table 4.12). The trees which were having larger number of nests (>5) differed significantly with the trees having lesser number of nests (<5) in height (*t*=-4.1937, *df*=36, *p*<0.001), DBH (*t*=-4.1937, *df*=36, *p*<0.001) and canopy spread (*t*=-3.1316, *df*=36, *p*<0.01).
Table 4.12 One-way ANOVA of the tree architecture among different tree species at Nagaon Greater Adjutant Stork nesting colonies during 1995-96 and 1996-97 breeding season

<table>
<thead>
<tr>
<th>Tree architecture</th>
<th>Nesting Tree (df=9, 170)</th>
<th>Non-Nesting Tree (df=27, 89)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>p value</td>
</tr>
<tr>
<td>Height</td>
<td>8.48</td>
<td>0.001</td>
</tr>
<tr>
<td>DBH</td>
<td>10.84</td>
<td>0.001</td>
</tr>
<tr>
<td>Canopy spread</td>
<td>5.50</td>
<td>0.001</td>
</tr>
</tbody>
</table>

It was seen that most of the nesting trees had 100% ground cover. Only single *Mitragyna parvifolia* was found without ground cover (Fig. 4.2).

4.4.2.2 Nest

I counted 51 and 52 nests in 1995-96 and 1996-97 respectively (Table 4.9). In the second nesting season there were eight species of nesting trees compared to ten species in the first year. The highest number of nests (11) were recorded on a single *Bombax ceiba* tree in both the year. In 1995-96, most of the nests were built on *Albizia lucida* (29.41%), while in 1996-97 most of the nests were built on *Alstonia scholaris* (25%). There was a significant difference between number of nests and number of tree species (one-way ANOVA, F=31.55, df=9,170, p<0.001).

The number of nest was highly correlated with height, followed by DBH and canopy spread (Table 4.13) but it was not correlated with NNTD and distance from a nearest house.

Table 4.13 Correlation between nest number and tree architecture, NNTD and nearest house at nesting colonies, Nagaon during 1995-96 and 1996-97 breeding season of Greater Adjutant Stork

<table>
<thead>
<tr>
<th></th>
<th>Height</th>
<th>DBH</th>
<th>Canopy spread</th>
<th>NNTD</th>
<th>Nearest house</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>r</em></td>
<td>0.7308</td>
<td>0.6451</td>
<td>0.5675</td>
<td>-0.1147</td>
<td>0.1639</td>
</tr>
<tr>
<td><em>p</em></td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.4930</td>
<td>0.3255</td>
</tr>
</tbody>
</table>

NNTD: Nearest nesting tree distance

n = 38
More than 90% of nests were built on flat horizontal branch(es) with or without an erect side branch. Also, more than 90% of nests were built on top canopy of the nesting tree.

It seems that among the nesting trees used in the colonies at Nagaon, GAS preferred *Bombax ceiba* and avoided *Artocarpus heterophyllus*, *Artocarpus lakoocha* and *Garcinia cowa* (Table 4.14).

Table 4.14 Tree species preference and avoidance by Greater Adjutant Storks at Nagaon (1995-96 & 1996-97)

<table>
<thead>
<tr>
<th>Nesting tree species</th>
<th>Relative Availability</th>
<th>Expected usage</th>
<th>Observed usage</th>
<th>Expected proportion usage</th>
<th>Confidence Limit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Alstonia scholaris</em></td>
<td>0.13</td>
<td>13.13</td>
<td>20</td>
<td>0.13</td>
<td>0.087</td>
<td>0.309</td>
</tr>
<tr>
<td><em>Albizia lucida</em></td>
<td>0.26</td>
<td>26.26</td>
<td>25</td>
<td>0.26</td>
<td>0.127</td>
<td>0.368</td>
</tr>
<tr>
<td><em>Artocarpus heterophyllus</em></td>
<td>0.08</td>
<td>8.08</td>
<td>3</td>
<td>0.08</td>
<td>0.000</td>
<td>0.077</td>
</tr>
<tr>
<td><em>Mitragyna parvifolia</em></td>
<td>0.16</td>
<td>16.16</td>
<td>12</td>
<td>0.16</td>
<td>0.028</td>
<td>0.209</td>
</tr>
<tr>
<td><em>Artocarpus lakoocha</em></td>
<td>0.08</td>
<td>8.08</td>
<td>3</td>
<td>0.08</td>
<td>0.000</td>
<td>0.077</td>
</tr>
<tr>
<td><em>Barringtonia acutangula</em></td>
<td>0.03</td>
<td>3.03</td>
<td>1</td>
<td>0.03</td>
<td>0.000</td>
<td>0.038</td>
</tr>
<tr>
<td><em>Ficus glomerata</em></td>
<td>0.11</td>
<td>11.11</td>
<td>10</td>
<td>0.11</td>
<td>0.015</td>
<td>0.183</td>
</tr>
<tr>
<td><em>Premna benghalensis</em></td>
<td>0.03</td>
<td>3.03</td>
<td>2</td>
<td>0.03</td>
<td>0.000</td>
<td>0.059</td>
</tr>
<tr>
<td><em>Garcinia cowa</em></td>
<td>0.08</td>
<td>8.08</td>
<td>3</td>
<td>0.08</td>
<td>0.000</td>
<td>0.077</td>
</tr>
<tr>
<td><em>Bombax ceiba</em></td>
<td>0.05</td>
<td>5.05</td>
<td>22</td>
<td>0.05</td>
<td>0.102</td>
<td>0.33</td>
</tr>
</tbody>
</table>

* Significant usage

The floristic survey in two randomly selected 100 sq. m area in Haibargaon nesting colony shows that there were 37 species of plants among which betelnut *Areca catechu* was found more than any other branching tree species (Appendix 4.3). However, bamboo was also found dominating.

4.5 DISCUSSION

4.5.1 Location

All the nesting colonies were found in village and semi-urban area in the Brahmaputra valley, Assam. Although nesting colony survey was restricted outside the protected forest area, I did not find nesting colony in other forest areas. Saikia and Bhattacharjee (1996a) found 11 nesting colonies including one in the Kaziranga National Park during their five years study (1989-94). Bhattacharjee and Saikia (1996) also found 90% of GAS nest outside the protected areas. Congeneric Marabou Stork *Leptoptilos crumeniferus* also
breed throughout the nonforested parts of tropical Africa (Pomeroy, 1977a). These colonies like most other colonial nesters (Pomeroy, 1977a) were traditional. As described by Barooah (1991) and Saikia and Bhattacharjee (1990a, b), I also found that same nesting colonies were amidst thick bamboo plantations.

During my study I did not find GAS nesting with other birds on the same tree or in the same colony. However, at Dichial, Sibsagar district one nest was found with Openbill Storks. In the late part of the last century, GAS were found to nest with Lesser Adjutant storks and pelicans in Mayanmar (Hume and Oates, 1890). Associations with one or more other species of bird can be seen in Marabou stork (Pomeroy, 1977a), and Openbill stork (Datta and Pal, 1993) also. Bhattacharjee and Saikia (1996) and Saikia and Bhattacharjee (1996a) reported GAS nesting with LAS in one colony. However, on a revisit to the Manaha colony in Morigaon district, on 19th October 1996 I saw one Lesser Adjutant Stork nest with 19 GAS nests built on five trees.

4.5.2 Habitat Relationship
The nearest nesting tree distance (NNTD) depicts compact colonial nature of GAS. Compactness is possible only where sufficient suitable trees are close together (Pomeroy, 1977a) and for the scattered Mvule Chlorophora exelsa trees Marabou colonies are less compact than those of many colonial species. Throughout the Brahmaputra valley and in the intensive study site, availability of suitable trees within the colony area provided GAS to nest in compact manner. In 1995-96 nesting season one nesting tree was found 400 m away from the Haibargaon nesting colony at Nagaon, which was a new nesting tree. But in the next season (1996-97) GAS did not make nest there. This might have happened due to high competition for nesting in 1995-96 (see chapter 5, section 5.3.2), because in the next season lesser number of trees were used in Haibargaon. Belles-Iks and Picman (1986) also observed in House wrens that intense competition might force some birds to select lower quality of nesting sites. Against the argument of Beaver et al. (1980) that availability of suitable vegetation influences nest dispersion more than social factors, Burger (1978) and Post (1990) opine that social interactions are the main organizing force in intra-colony nest dispersion, particularly in homogenous habitat. In GAS nesting colony also, it appears that in addition to the suitable tree availability, social interactions influences them to colonise in a compact manner.
Nesting colonies were situated very near to the human settlement and public road which are indicator of human tolerance. Other storks which are found in association with human settlements are Marabou Stork in Africa (Pomeroy, 1977a), Openbill Stork in India (Datta and Pal, 1993; Mukhopadhyay, 1980) and Painted Stork in India (Desai, 1971; Urfi, 1989). Datta and Pal (1993) describe human disturbance causes mortality of Openbill nestlings. Saikia and Bhattacharjee (1996a) are of the opinion that the selection of nesting sites in urban areas by GAS is directly related with their evolutionary process of niche separation from their smaller cousin Lesser Adjutant stork Leptoptilos javanicus.

Only two years intensive study at Nagaon is not adequate to reveal gradual influence of human activity in the nesting ecology of GAS. The Number of nests collectively at two colonies at Nagaon was stable in two successive nesting seasons. However, tree felling and building of new houses very near to the colony is a clear sign of habitat alteration. There are several records of colonies of Marabou Stork having been abandoned (Pomeroy, 1977a). The birds had to leave traditional sites when the trees they used for nesting were felled. Degradation of nesting habitats were reflected in GAS by the shifting of the nesting sites (Saikia and Bhattacharjee, 1996a). In Haibargaon nesting colony also, GAS used fewer nesting trees in the second nesting season. However, long duration study is required to see whether it was the immediate effect of tree felling or was a matter of nesting success fluctuation which may be seen in colonial birds in different nesting seasons. It seems that a strong site fidelity and traditional nesting trees encourage GAS to build nest in a particular place year after year even when gradual change of the habitat is taking place.

Though most of the nesting trees were found in close proximity to human habitation, they were in the thick vegetation cover. Small patches of natural forest and mix plantation dominated by bamboo clump near house characterise typical feature of the nesting colonies. The dense bamboo vegetation around the nesting trees apparently act as a shield from thunder storm during the pre-monsoon in March-May (see Chapter 2, section 2.4b). The thick ground cover including shrubs Tragia involucrata whose leaves are irritating to skin, and smaller trees below the nesting trees make them unapproachable. Apparently these are the specific feature for GAS nesting habitat.
The distance to the nearest water source and foraging ground never exceeded beyond five and seven km respectively from the respective colonies. This finding resembles with Bhattacharjee and Saikia (1996) and Saikia and Bhattacharjee (1996a). They describe aquatic and terrestrial feeding sites. In my study also, water source often coincides with foraging ground and GAS utilized wetlands as their feeding site as well. The distance to the water source also varies according to the flooding condition during the course of breeding season. However, terrestrial foraging sites e.g., garbage dumps are permanent.

Food supply should be available within flying range of the breeding colony (Berry et al., 1973). The choice of sites of breeding colonies seems to be determined primarily by availability of food (Pomeroy, 1977a). Kushlan et al.(1975) and Kushlan (1986) are also of the opinion that unsuccessful stork nesting has been related primarily to reduced food supplies and loss of nesting habitat. For the settlement of a colony by herons, Fasola and Alieri (1992b) observe that the abundance of foraging habitats and inter-heronry distances may be more important than vegetation structure. Congeneric Marabou Stork nesting colonies were situated near large swamp, lake or river (Pomeroy, 1977a; 1978a). Lack (1968) considered that colonial nesting in storks is found in those species having a locally abundant food supply. Ogden (1986) found foraging areas of Wood Storks from the breeding colony ranged between 15-56 km. Coulter (1989b) also found that 62% of feeding areas were within 10 km from the Wood Stork nesting colony.

All these findings support the fact that close distance to water source and foraging habitat facilitates GAS nesting colonies. It is seen that Wood Stork often fly as far as 40 km from their colony to forage (Kahl, 1964). Marabou Stork (Pomeroy, 1977a) as well as White Pelican Pelecanus onocrotalus also fly long distances to secure food from nesting colony (Pyrovetsi, 1989). GAS like other soaring bird may travel to a long distance in search of food, which however, may retard the rate of foraging trip to the nestlings. In this regard, closer distance to the foraging ground certainly is an aid for the nesting colonies.

Conner and Adkinsson (1977) observed that Principal Component Analysis (PCA) is a valuable tool in evaluating multivariate habitat relations for five species of Woodpecker. Similar kind of study have been done by McCrimmon (1978) and Beaver et al.(1980) in
mixed heronry applying PCA. I have done PCA only on the habitat parameters. It reveals that human activity factors (nearest house and road) are negatively correlated to PC I; while nearest water source and foraging ground are more positively correlated to PC I. However, it seems that compared to food availability, distance to nearest forest which is negatively correlated to PC II is less important for GAS.

4.5.3 Nest

Sixty five active nests were counted throughout the Brahmaputra valley during the breeding season of 1994-95. Saikia and Bhattacharjee (1990a, b) discovered 75 active nests during 1989-90. However, these data should be discussed in relation to the duration of survey. Three months long survey from one end to the other end of the valley might affect the actual number of nest (see Chapter 3 also). Nesting in different colonies might be asynchronous; in a colony also there might be early and late breeder (see chapter 5, section 5.3.7.3). Throughout the breeding season, number of nest on a particular tree might not be stable. Therefore, during my earlier part of the survey I might have missed the late built nests; while in the later part of the survey some birds might either have abandoned or vacated the nests before I visited the colony. But in the intensive study area at Nagaon, due to the daily monitoring I was able to record only the maximum number of nest(s) on a particular tree during each breeding season. The maximum number of nest per tree most likely depict the nesting capacity of a particular tree. I found as many as 11 nests on a particular Bombax ceiba at Nagaon in two successive seasons which is recorded as the highest number of nests on a single tree. In Marabou Stork, it is seen that more than 30 nests can be built on a single tree; the highest record being 53 (Pomeroy, 1978a).

Most of the nests were built in the top canopy which facilitates easy movement to and from the nest. Though the tree height in different colonies varied, yet the relative nest height did not differ significantly throughout the valley. This suggests that no matter the tree height, GAS prefers to nest in a specific ratio of nest height/ tree height; i.e. in the top canopy. In American Red star, it is found that the nest height was significantly correlated with both the height of the nest tree and the relative nest height (Morris and Lemon, 1988). In mixed heronry, the mean height of the nest of each species correlated positively with mean vegetation height (Burger, 1979; Post, 1990). Some birds presumably position
their nest to get more solar radiation which may affect nest temperature and thus the amount of incubation required (Martin and Roper 1988; Kendeigh, 1963). As GAS breed in winter and their breeding season lasts long (Saikia and Bhattacharjee, 1996a), one of the reasons of nesting in the top canopy probably is for gaining heat from sun.

Unlike some opportunistic nester e.g., Bald eagle which is found to use a variety of substance for nesting- trees, cliffs, sea stakes, pinnacles (Anthony and Issacs, 1989) and Marabou Stork which also nest on cliffs (Pomeroy, 1977a), the GAS are found to nest build only on trees. However, in the late part of the last century, they were found to nest on pinnacles of the rocks and on large trees in Mayanmar (Hume and Oates, 1890). Due to their huge platform shaped nest (Ali and Ripley, 1987) GAS requires large space and sparse foliage cover in the nest site and probably because of that most of the nests were built on flat horizontal or slightly inclined branches parallel to the ground. They are rarely found to build nest on “Y” fork. Though I did not measure nest space, it is seen that the minimum distance between the two nests was approximately one meter. Marabou Stork is found to nest as close as 1.5 meters (Pomeroy, 1978a).

The number of nest did not correlate with the nesting tree architecture and habitat parameters during the nesting colony survey in the Brahmaputra valley; but it was higly correlated with height, DBH and canopy spread of the nesting trees at Nagaon study site and there was no correlation with NNTD and nearest house. This difference in the result may be due to the possibility that during surveys I could not get proper data on nesting ecology as has been discussed in the earlier part of this section. Studies at Nagaon indicate that GAS presumably build more nests on larger tree. Although NNTD was found short in GAS nesting colony, i.e., the nesting trees were close to each other, number of nests showed no correlation with NNTD and nearest house. Though compactness might have no relation with the number of nest it appears that GAS are highly colonial. It seems that GAS at Nagaon has become adapted to build nest near houses. No direct human disturbance to the birds and nests are remarkable.

**4.5.4 Nesting and Non-nesting Trees**

Throughout the Brahmaputra valley and in the intensive study area, the nesting trees were found to be larger and significantly different in structure with the respective non-nesting
trees around them. Though different species of non-nesting trees were found in different colonies, however, they did not vary in DBH and canopy spread and they were smaller than their respective nesting trees. This indicates that GAS discard smaller trees for nesting, and selecting bigger trees for nesting. This finding agrees with Saikia and Bhattacharjee (1996a) who state that the selection of the nesting site by GAS depends on the presence of tall and branched trees intermixed with bamboo clumps. In mixed heronry also it is found that birds generally prefer taller trees (Venkatraman, 1996; Fasola and Alieri, 1992) and largest species nest at highest level (Burger, 1979). The Wood Storks also consistently nest on larger DBH trees at fresh water sites (Rodgers et al., 1996).

Many authors explain the cause of selecting larger trees by birds. Burger (1979) believes that the advantages of nesting high in mixed species colonies for heron are: (1) increased ability to see predators from a distance, (2) easy flight access to, and departure from the nest, (3) maximum distance from ground or water predators, and (4) maximum distance from the threat of flooding in low-lying colonies. Her first hypothesis is supported by Mori (1980) that taller trees provide good visibility; while the second hypothesis is agreed by Brown and Amadons (1978), McEwan and Hirth (1979), Fasola and Alieri (1992a) and Wood et al. (1996) in different studies.

During my study I did not find any predator climbing up to the nest to get a nestling. Unlike in Wood Stork colony where raccoons are the main predators (Coulter and Bryan, 1995; Ruckdeschel and Shoop, 1987), the GAS is not known to have such type of predators. There was also no threat of flooding in colonies. Therefore I assume that GAS select taller trees due to probably easier access to nest and greater visibility of the surrounding area.

The larger sized trees are capable of providing greater space and more nest sites (Bergin, 1992). Wood Storks also use older trees because they provide better support and stability for nests (Rodgers et al., 1996). In the intensive study area at Nagaon, it was found that nesting trees with larger number of nests were bigger than other nesting trees with lesser number of nests. These bigger trees were consistently used by GAS with almost equal number of nests in both nesting seasons.
It is found that GAS used not more than ten species of trees for nesting. The most frequently used trees in descending order were *Alstonia scholaris*, *Mitragyna parvifolia* and *Bombax ceiba* during the nesting colony survey. Barooah (1991) also reported that *Bombax ceiba* and *Alstonia scholaris* were the nesting trees found in a colony in Sibsgar district. Bhattacharjee and Saikia (1996) found 13 tree species for the purpose of nesting among which *Bombax ceiba*, *Mitragyna parvifolia* and *Alstonia scholaris* were often used.

In the intensive study site at Nagaon, *Albizzia lucida* was largely used by GAS for nesting (35%) compared to other species in the first nesting season. However, in the next season usage of *A. lucida* declined to 17% (Table 4.9). It is found that the relative abundance of this species in the Nagaon nesting colony was more (Appendices 4.2 & 4.3). In the first nesting season more number of GAS had arrived than in the second nesting season (see chapter 5, section 5.3.2). Therefore, most probably due to its relative abundance, more number of *A. lucida* was used in the first season. On the other hand, though number of *Alstonia scholaris*, *Bombax ceiba*, *Mitragyna parvifolia* were less in the colony (Appendices 4.2 & 4.3), they were exclusively used in both the seasons (Table 4.9).

Different studies in bird show that birds either may be selective for particular type of plant or they may be adaptive to different vegetation. Though herons adapt to the available vegetation (Beaver *et al*., 1980), in heterogenous heronries the species do not nest randomly with respect to the vegetation but select particular plant species (Burger, 1979). Grey and purple herons are favoured by specific types of vegetation (Fasola and Alieri, 1992a). Egrets also showed a marked preference for specific tree species (Venkataraman, 1996). In the south and east of Uganda, at least 87% of the nests of Marabou Storks were found in Mvule trees (Pomeroy, 1973).

On the contrary, Openbill Stork (Datta and Pal, 1993) and Woods Stork in estuarine sites (Rodgers *et al*., 1996) were found to utilise a variety of plant species for nesting.

The result of the nesting tree species preference by using the technique of utilization-availability data analysis reveals that in the intensive study colonies at Nagaon, GAS apparently preferred *Bombax ceiba*; while avoided *Artocarpus heterophyllus*, *Artocarpus lakoocha* and *Garcinia cowa* among the nesting trees. *Bombax ceiba* was the largest tree.
and ‘avoided’ trees were smaller. The Marabou Storks nest on various tree species, but the main requirement being strong terminal branches (Pomeroy, 1978a). Mvule trees were found to be excellent for nesting of Marabou Stork because of their strong branches (Pomeroy, 1977a). Being a massive bird, the congeneric GAS also requires strong branches, and sparse canopy for the free movement to and from nest. Moreover, it also needs suitable side branch near the nest to perch. More canopy spread indicates wide branching pattern. The GAS may not be species specific for nesting tree, but the frequently used tree species are characterised by large tree having wide branching pattern, thin foliage cover and with more canopy spread.

In conclusion, it can be assumed that most likely GAS prefer to nest in compact colony on large, widely branched trees with thin foliage cover amidst thick vegetation cover below the tree, preferably by bamboo ‘screen,’ near the food and water source in traditional site with less human disturbance.
APPENDIX 4.1

List of non-nesting tree species around the 10 m radius of the nesting trees of Greater Adjutant Stork nesting colonies throughout the Brahmaputra valley, Assam during 1994-95 breeding season.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albizzia lucida</td>
<td>6</td>
</tr>
<tr>
<td>Alstonia scholaris</td>
<td>2</td>
</tr>
<tr>
<td>Artocarpus heterophyllus</td>
<td>3</td>
</tr>
<tr>
<td>Artocarpus lakoocha</td>
<td>1</td>
</tr>
<tr>
<td>Bischofia javanica</td>
<td>1</td>
</tr>
<tr>
<td>Bombax ceiba</td>
<td>2</td>
</tr>
<tr>
<td>Cassia fistula</td>
<td>2</td>
</tr>
<tr>
<td>Cedrara toona</td>
<td>1</td>
</tr>
<tr>
<td>Dillenia indica</td>
<td>1</td>
</tr>
<tr>
<td>Dysoxylum spp.</td>
<td>1</td>
</tr>
<tr>
<td>Ficus glomerata</td>
<td>2</td>
</tr>
<tr>
<td>Garcinia spp.</td>
<td>2</td>
</tr>
<tr>
<td>Mangifera indica</td>
<td>3</td>
</tr>
<tr>
<td>Moringa oleifera</td>
<td>1</td>
</tr>
<tr>
<td>Pongamia pinnata</td>
<td>1</td>
</tr>
<tr>
<td>Streblus aspera</td>
<td>7</td>
</tr>
<tr>
<td>Unidentified</td>
<td>1</td>
</tr>
</tbody>
</table>
APPENDIX 4.2

List of non-nesting tree species around the 25 m radius nesting tree of Greater Adjutant Stork nesting colonies at Nagaon during 1995-96 and 1996-97 breeding season.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artocarpus heterophyllus</td>
<td>11</td>
</tr>
<tr>
<td>Artocarpus lakoocha</td>
<td>3</td>
</tr>
<tr>
<td>Cassia fistula</td>
<td>6</td>
</tr>
<tr>
<td>Cedrela toona</td>
<td>3</td>
</tr>
<tr>
<td>Cida cordifolia</td>
<td>3</td>
</tr>
<tr>
<td>Cryptocarya amygdalima</td>
<td>2</td>
</tr>
<tr>
<td>Dysoxylum spp.</td>
<td>2</td>
</tr>
<tr>
<td>Ficus benjamina</td>
<td>1</td>
</tr>
<tr>
<td>Ficus glomerata</td>
<td>4</td>
</tr>
<tr>
<td>Ficus religiosa</td>
<td>1</td>
</tr>
<tr>
<td>Garcinia cowa</td>
<td>1</td>
</tr>
<tr>
<td>Garcinia morella</td>
<td>1</td>
</tr>
<tr>
<td>Garcinia spp.</td>
<td>2</td>
</tr>
<tr>
<td>Holarrhena autidysenterica</td>
<td>1</td>
</tr>
<tr>
<td>Mangifera indica</td>
<td>5</td>
</tr>
<tr>
<td>Melotus philipensis</td>
<td>2</td>
</tr>
<tr>
<td>Moringa oleifera</td>
<td>1</td>
</tr>
<tr>
<td>Olea europea</td>
<td>3</td>
</tr>
<tr>
<td>Phyllanthus emblica</td>
<td>1</td>
</tr>
<tr>
<td>Premna benghalensis</td>
<td>2</td>
</tr>
<tr>
<td>Taminalia citrina</td>
<td>1</td>
</tr>
<tr>
<td>Trapa bisbinosa</td>
<td>3</td>
</tr>
<tr>
<td>Trewia nudiflora</td>
<td>1</td>
</tr>
<tr>
<td>Streblus aspera</td>
<td>4</td>
</tr>
<tr>
<td>Syzygium cumini</td>
<td>1</td>
</tr>
</tbody>
</table>
### APPENDIX 4.3
List on non-nesting plant species in the Haibargaon nesting colony of Great Adjutant Stork at Nagaon

<table>
<thead>
<tr>
<th>Species</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albizzia lucida</td>
<td>94</td>
</tr>
<tr>
<td>Alstonia scholaris</td>
<td>3</td>
</tr>
<tr>
<td>Areca catechu</td>
<td>743</td>
</tr>
<tr>
<td>Artocarpus heterophyllus</td>
<td>35</td>
</tr>
<tr>
<td>Artocarpus lakoocha</td>
<td>8</td>
</tr>
<tr>
<td>Averrhoa corambola</td>
<td>3</td>
</tr>
<tr>
<td>Azadirachta indica</td>
<td>2</td>
</tr>
<tr>
<td>Bambusa spp.</td>
<td>35</td>
</tr>
<tr>
<td>Bombax ceiba</td>
<td>2</td>
</tr>
<tr>
<td>Borassus flabellifer</td>
<td>1</td>
</tr>
<tr>
<td>Cassia fistula</td>
<td>14</td>
</tr>
<tr>
<td>Cida cordifolia</td>
<td>6</td>
</tr>
<tr>
<td>Citrus grandis</td>
<td>1</td>
</tr>
<tr>
<td>Cocos nucifera</td>
<td>28</td>
</tr>
<tr>
<td>Cryptocarya amygdalina</td>
<td>4</td>
</tr>
<tr>
<td>Dillenia indica</td>
<td>1</td>
</tr>
<tr>
<td>Erythrina spp.</td>
<td>1</td>
</tr>
<tr>
<td>Eucalyptus spp.</td>
<td>1</td>
</tr>
<tr>
<td>Ficus benjamina</td>
<td>1</td>
</tr>
<tr>
<td>Ficus glomerata</td>
<td>10</td>
</tr>
<tr>
<td>Ficus religiosa</td>
<td>1</td>
</tr>
<tr>
<td>Garcinia cowa</td>
<td>2</td>
</tr>
<tr>
<td>Garcinia spp.</td>
<td>5</td>
</tr>
<tr>
<td>Garcinia xanthochymus</td>
<td>2</td>
</tr>
<tr>
<td>Gymnema arborea</td>
<td>8</td>
</tr>
<tr>
<td>Holarrhena autoidysenterica</td>
<td>1</td>
</tr>
<tr>
<td>Livistona jenkinsiana</td>
<td>2</td>
</tr>
<tr>
<td>Mangifera indica</td>
<td>14</td>
</tr>
<tr>
<td>Machilus bombycina</td>
<td>1</td>
</tr>
<tr>
<td>Melotus philipensis</td>
<td>14</td>
</tr>
<tr>
<td>Messua ferrea</td>
<td>1</td>
</tr>
<tr>
<td>Mitragyna parvifolia</td>
<td>1</td>
</tr>
<tr>
<td>Moringa oleifera</td>
<td>1</td>
</tr>
<tr>
<td>Olea europa</td>
<td>2</td>
</tr>
<tr>
<td>Oryxylum indicum</td>
<td>1</td>
</tr>
<tr>
<td>Premna benghalensis</td>
<td>1</td>
</tr>
<tr>
<td>Streblus aspera</td>
<td>10</td>
</tr>
<tr>
<td>Syzygium spp.</td>
<td>2</td>
</tr>
<tr>
<td>Tamarindus indica</td>
<td>1</td>
</tr>
<tr>
<td>Tarminalia eitrina</td>
<td>1</td>
</tr>
<tr>
<td>Trewia nudiflora</td>
<td>4</td>
</tr>
</tbody>
</table>

* Bamboo was counted as clump.
Chapter 5

BREEDING BIOLOGY
CHAPTER 5

BREEDING BIOLOGY

5.1 INTRODUCTION

The most essential part of the life cycle of a species is breeding which keeps the gene flow from one generation to the next generation. From the conservation point of view, the study of breeding biology is very important which is crucial factor for the population growth and stability.

In this chapter I will present my results of breeding biology of GAS right from the nest building to the fledging of young in the North Haibargaon breeding colony in two successive breeding seasons.

The objectives of the study were to know the breeding behaviour, parental care, parental investment, development of the chick up to the fledgling stage and reproductive success in GAS.

5.2 METHODS

5.2.1 METEOROLOGICAL INFORMATION

Daily temperature (maximum and minimum), humidity (morning and afternoon) and rainfall of two breeding seasons (1 September 1995 to 30 June 1996 and 1 September 1996 to 31 May 1997) were collected from the Meteorological Department of Regional Agricultural Research Station, Shillongoni, Nagaon under Assam Agriculture University, Jorhat. Monthly mean was taken of each parameter from the daily data.

5.2.2 CHRONOLOGY

Storks were observed from the first week of September, when they had started arriving to the site, till the end of May when all nests were vacated. Daily monitoring was done twice (morning and evening) with the help of the field assistant by counting the adult storks on nests as well as nesting and non-nesting trees in the colony.
Analysis

Monthly average number of storks was taken for morning and evening count separately. However, only the paired data of morning and evening count per day were taken into consideration i.e., if only morning count was possible for a particular day, that day was dropped from the average and vice versa. Each nesting tree and nest(s) on it were assigned a code to avoid the counting error (see Appendices 5.1 and 5.2 for explanation of code numbers).

5.2.3. GENERAL BREEDING BIOLOGY

Each year a tall watch tower (machan) was built to observe the colony from the nest building or incubation stage. The height of the machan was equal to the height of the nests or just above the nests. The observation continued till the focal nests were either vacated or abandoned. A nest was considered to be abandoned when the stork pair stopped visiting before laying eggs, or no eggs hatched and the pair left the nest, or if all the nestlings died and the parents stopped attending the nest. A nest was considered vacated when the last nestling of the clutch fledged.

During the first breeding season, from 1 November 1995 to 21 April 1996 I observed breeding pairs in five nests simultaneously from a 20.5 m high machan. There were three nesting trees - two of them had one nest each and one tree contained three nests (Mj3 A, Mj4 A, Mj1 A, D, C; Appendix 5.1). Later on, in the last week of November and first week of December 1995, three more nests were built (Mj4 B,C,D) in Mj4 where there was only one nest earlier. Out of the eight nests, five early built nests were observed from incubation stage, while later nests were observed from the nest building stage. However, Mj4 C and D were later abandoned so six nests could be observed till
Plate 1. The watch tower (machan) during 1996-97 breeding season. The arrow shows the nest. The author is standing in front of the machan.
the fledging of juveniles. The average distance between the machan and the nests was 13 m.

During the second breeding season, from 8 November 1996 till 12 May 1997 I observed breeding pairs on five nests from a 23 m high machan. There were three nesting trees: two of them had two nests each (D1 D, E and K2 A, C) and the other tree contained one nest (Jk1 A; see Appendix 5.2). Later on, two nests (D1 D and E) were abandoned and I could observe three other nests till the juveniles fledged. These three nests were observed from incubation stage. The distances between the machan and nests were 12 m, 30 m and 60 m for nests on K2, Jk1 and D1 respectively.

I observed breeding behaviour of the focal pairs continuously from dawn to dusk (0500 to 1700 hrs.) each day, six day a week. However, duration of observation decreased up to 11 hrs. a day during the shorter days of winter (0545 to 1645 hrs.). Though only day light observations were done, it was assumed that the individuals seen in the late evening would be staying throughout the night because the next morning, the same individuals were seen again.

Individuals of the focal pairs were identified by their natural markings, facial and bill patterns and individual idiosyncracies. The gender of the individuals were determined by copulation position. I found that the males were slightly larger than the females, which was also an additional aid for identification of a male and a female of a pair (see also Kahl, 1972). Moreover, I sketched facial patterns and noted important identification
characters in ‘face cards’ (see Coulter and Bryan JR., 1988 and Coulter, 1989b). The sketches were redrawn regularly when the facial pattern of the stork would change.

In addition to the focal nests, I observed breeding behaviour of other storks in the colony as far as possible and data were noted separately. Descriptive account of the morphological and behavioural changes of the chick to fledgling was recorded in field note book. A juvenile was distinguished from a chick when the snowy white down feathers of the chick were replaced by the blackish brown juvenile feather.

5.2.4. PARENTAL INVESTMENT

I recorded time budgets of parents in the focal nests continuously during the day time. The time of arrival and departure of each individual was recorded to know how much time it spent in the nest. Duration of following seven activities in the nest by each partner of a pair was recorded.

(i) **Incubation**: When the parent sat on the egg(s) till the hatching of all egg(s). It also included brooding of other chick(s) which had hatched earlier in more than one egg clutch.

(ii) **Reclining**: When the parent sit on the nest other than incubating.

(iii) **Standing**: When the parent stood in the nest or on nearby branch other than doing wing stretching, nursing, nest arrangement and re-ingestion. Standing included auto-preening and bill clattering which were not related to the nestlings.

(iv) **Wing stretching**: When parent shaded the young in the nest from the sun by stretching both wings, one wing or both wings half folded.
(v) Nursing: When parent preened the young.

(vi) Nest arrangement: When the parent arranged the nest materials (sticks, leaves or tree twigs) with the help of bill and legs, or when it cleaned the nest by dropping down old nest materials.

(vii) Re-ingestion: When the parent re-ingested food from the nest floor which had been regurgitated by itself to feed the young.

**Analyses**

I observed six and three nests in the first and second breeding season respectively till the juveniles fledged. Due to the limited time available for writing the thesis, I have randomly taken one nest from each season for analysis. The Mj1 B nest (see Appendix 5.1 for detail) of the first breeding season was observed since 1 November 1995 to 23 February 1996. The total duration of observation was 613 hrs. The K2 A nest (see Appendix 5.2 for detail) of the second breeding season was observed from 8 November 1996 to 31 March 1997. The total duration of observation was 626 hrs.

(i) Activities by parent storks according to young-age: From the hatching of the first chick in the nest, age of the young was categorised at every ten days of interval till the fledging of last young from the nest i.e. 10 days, 20 days, 30 days and so on. Duration in percentage of each activity of male and female stork on the nest and their absence from the nest at every young-age was calculated separately.

(ii) Activities by each parent at different time of day: I divided a day into three parts: 0500 to 1000 hrs., 1000 to 1400 hrs. and 1400 to 1700 hrs. The percentage of
duration of each activity of both the parents on the nest was separately calculated for three parts of the day.

5.2.5. DIFFERENT TYPES OF TRIPS

I found that GAS made different types of trips from the initiation of nest building activity to the fledging of the last young one. They used to leave the nest and come back with or without something. Each trip was coined according to the material they brought.

(i) Nest material trip: When the stork returned with nest material the trip was referred as nest material trip.

(ii) Foraging trip: When the stork brought food for the young the trip was called as foraging trip.

(iii) Water trip: When the stork brought water it was coined as water trip.

(iv) Miscellaneous trip: When the stork returned without anything I could not be determined the reason for the trip, so I referred it as miscellaneous trip.

Analyses

(i) Total number of each trip by the male and female separately in the whole breeding season was calculated.

(ii) Number of frequency of each trip per day by the parents together according to the young age was calculated.

(iii) Number of each trip by the parents collectively in different time of the day throughout the breeding season was counted.
5.2.6. REPRODUCTIVE SUCCESS

During the daily monitoring in the colony (as described in the section 5.2.2) breeding activities of each nest were also recorded. A nest was considered completed when the stork started incubation. Nesting attempts and re-nesting were also counted. Re-nesting was considered only when at the same position of the abandoned nest, a new nest was built.

The hatching success was not possible to find, because egg(s) could not be seen in every nest from below. To find out the clutch size, I followed Coulter (1989b). The nest in which I could not count the egg(s), I noted the maximum number of chicks as an estimate of the number of egg(s) laid. This was a minimum estimate.

A nest which produced at least one hatchling was regarded successful. The nesting success was calculated as the percentage of successful nest out of the total nests built. Fledging success was calculated as the percentage of young fledged out of the total chicks hatched from total nests built, or number of young fledged per nest. However, fledging success was also calculated only from of the successful nests.

5.2.7. INCUBATION AND FLEDGING PERIOD

The incubation period of a pair of storks was estimated as the period from the initiation of incubation till the hatching of their first chick. The initiation of incubation was considered when soon after nest building parents began reclining and behaving as if they were caring for egg (see Coulter, 1989b). Incubation in stork starts with the laying
of the first egg (Kahl, 1966b). It was however, difficult to know the exact date of hatching from below the tree. Daily monitoring proved to be a useful tool in this regard. The hatching of each nest was guessed by hearing the first call of the chick, finding broken fresh egg shell below the tree or observing the parent’s posture and behaviour in the nest. I found in the focal nest that just after hatching the parent stork would stand with its legs apart, pointing the bill towards the floor of the nest (to the new hatchling) and regurgitate or re-ingest food. To supplement this, another method was applied. When the chick was first seen its probable age was subtracted to get the hatching date (see also Kahl, 1966b and Pomeroy, 1978a).

The fledging period was considered as the duration from the hatching of the first chick to the first fledging of a juvenile from a nest, assuming that the same juvenile was the first chick. Before finally leaving the nest, juvenile(s) might be doing several flying practices and eventually fly away from the nest for some time. During a daily census they might be missed due to this temporary absence and in the next daily census they might be seen again. To avoid this problem, if one juvenile was not seen continuously for a week, it was regarded fledged and the fledging date would be the date since when it was absent continuously.

**Analyses**

Mean incubation and fledging period were calculated for each breeding season separately. In three cases where incubation period exceeded more than 55 days, it was considered as re-laying of egg(s) and such nests were excluded from the analysis (see later section 5.4.3 for explanation). To get a more accurate incubation period, mean
incubation period was taken from five nests of both seasons where date of egg laying and hatching was observed from the *machan*.

**Hypothesis:** There is no significant difference of incubation and fledging period between the two seasons.

Due to small sample size, Mann-Whitney 'U' test was performed.

All the above analyses of breeding were done by STATA 5.0 program (Stata corp., 1993).

### 5.3. RESULTS

#### 5.3.1. METEOROLOGICAL INFORMATION

There was more rainfall in the first breeding season than in the second breeding season (Figs. 5.1 a & 5.1 b). Throughout the first breeding season there was rainfall. The highest rainfall occurred in the beginning of the of the season (September). There was no rainfall in November and December in the second breeding season and there was lesser amount of rainfall in the beginning of the season in comparison to the rainfall of the first breeding season. The second breeding season was colder than the first breeding season. January, in the middle of the breeding season was found to be the coldest and more humid month in both the seasons. Humidity was more in the first breeding season which decreased from February onwards.
Fig. 5.1a Meteorological information of Nagaon (1995-1996)

Fig. 5.1b Meteorological information of Nagaon (1996-1997)
5.3.2. CHRONOLOGY

Seven and nine months data (November 1995 through May 1996 and September 1996 through May 1997) were collected in the first and second breeding seasons respectively. Storks were found to come to the breeding colony from the first week of September. In both the seasons, the number of storks increased to a peak in the early part of the season and gradually declined to almost zero in May. In the first season of my study, the highest aggregation of storks was found in December while in the second breeding season, I saw highest number in October (Figs. 5.2 a & 5.2 b). But over all, the population trend of the Greater Adjutant Storks in the study area was similar in both breeding seasons. In all the months in both the breeding seasons, less number of storks were counted in the morning than in the evening. Number of storks were more in the first breeding season than in the second.

5.3.3. GENERAL BREEDING BIOLOGY

5.3.3.1 PRE-CHICK HATCHING PERIOD

(a) External morphological changes: At the onset of the breeding season I observed that the Greater Adjutant Stork underwent conspicuous morphological changes which made it a brilliantly coloured bird. The pale whitish wing band of the greater secondary coverts of the non-breeding season became bright silvery white in colour. The upper parts of the body including back, wing, tail and mantle turned to bluish grey from slaty grey or blackish grey. The under-tail coverts which were white at their base and dark smoky grey at the tip, became more fluffy. The colour of the head and nape became bright red. Black pigment occurred over the pale red part between the head and
Fig. 5.2a Population trend of Greater Adjutant Stork in North Haibargaon Nesting Colony (1995-96)

Fig. 5.2b Population trend of Greater Adjutant Stork in North Haibargaon Nesting Colony (1996-97)
forehead. The skin of the face and forehead appeared rough and encrusted with dark spots. The base of the bill, just below the dark skin, turned pinkish in colour. The neck turned to bright yellow with pinkish tinge. The dorsal air sac looked flashy red encircled by ruff of white feathers. The gular pouch appeared bright red.

I found that the female was brighter than the male. All breeding pairs wore the breeding plumage except one dull coloured male stork. There were some 'new adults' in the colony which despite brilliantly coloured were smaller in size and had few erect hair on their head and black hair suspending from the tip of the gular pouch. They were most probably younger storks.

As the breeding progressed the breeding pairs gradually regained their non-breeding colour. During mid January, the colour of the upper part turned to ashy grey, head, neck and forehead became paler from bright red and dark black respectively. The silvery white wing band also faded. In April, they looked like non-breeding storks with blackish upper part and dirty wing band.

(b) Crowding: In the beginning of the breeding season crowding of breeding storks took place. During this period some aggressive interactions occurred among the storks which included chasing, fighting, vocalisation, bill clapping and frequent flying from branch to branch and tree to tree. A dull coloured stork and some sub adult storks also visited the colony. However they were not found to take part in the crowding. The crowding occurred due to the competition for pair formation and suitable berth for
Plate 2a. One of the nesting trees in North Haibargaon nesting colony. Note the wide branching pattern of *Alstonia scholaris*.

Plate 2b. The 'crowding' on *Albizzia lucida* during 1995-96 breeding season.
nesting. A stork would be followed by another and within a short time more storks would gather on a tree. At this time, a stork perched on a branch, might be adjacent to another stork, would stretched its wings, slightly curve forward, bent its neck downward and bring the open bill between its feet. At the same time the tail would be cocked and the stork would make a long squeal 'qui-e-e-i', like Black kite *Milvus migrans* does, or would make a loud booming nasal sound ‘we-i-nh’. The storks were also found to make loud and deep ‘woom’ sound like the “lowing of a cow” (see Hume and Oates, 1890).

Later on, I found that between a pair, female stork was more vocal than the male and generally made squeal and nasal ‘we-i-nh’ which gradually became faint later in the breeding season. This high pitch vocalisation would be accompanied by occasional bill clattering while the bill pointed upward.

The crowding could occur on one or two trees in the colony at the same time. Each stork made a small territory of its own and would not allow other stork to come within it. The approach of other storks to this territory resulted in ferocious fights. Sometimes crowding was found continuously for ten to fifteen days on a particular tree. These activities started in the morning, gradually declined at noon and again increased towards on the evening. When some storks formed pair and selected nesting sites, the remaining storks moved to other trees for crowding.

These activities sharply increased to a peak in the beginning of the breeding season and gradually declined to nil in the later part of the breeding season. As many storks settled down for nesting, some storks which were unable to find a partner, still crowded
around to disperse the pairs and invade the nests. I termed these storks as 'floating storks', most of them which were 'new adults'. This sort of crowding was found as late as the last week of January.

(c) Pair formation and courtship: During the process of crowding, a male GAS would create a territory on a potential nest site where the nest would be built later on, and chased other GAS which came near to him. He announced his valour by frequent loud bill clattering, pointing the bill upward, or downward, or horizontal. He also poked sharply in the air with frontal arched body and half folded wings towards its breast. When he accepted a female GAS, after the pair formation both perched closely. A third GAS was often found near a pair which tried to break the bond. Later it was proved that in most of the cases the third was a female. The female of the pair was more aggressive than the male to chase away her rival. In two cases in the first breeding season 1995-96, I found that the third GAS (i.e., the second female) temporarily replaced the first female of the pair, but later she was replaced by the first female. The male easily accepted the new partner.

In some cases, the newly formed couple was found to perch closely for two to three days continuously before building the nest. During this period probably they even did not go for foraging. I saw both the male as well as the female take initiative in the courtship display, which though in general was similar but varied slightly among different pairs. A male would pluck a fresh twig from a nearby branch and put it near the feet of the female, or after holding it for few minutes he might drop it. He would
Plate 3a. A newly formed pair of the Greater Adjutant Stork (left) and a third unpaired stork is watching.

Plate 3b. The mating of the Greater Adjutant Stork (right) on the nest site. The other stork (left) is on its nest.
touch and gently grasp one of the female's tarsi with his bill. Some times the female also touched her own legs. She would withdraw her foot whenever a male grasped. Once, a male pulled one of her primaries. He gently clasped her bill, touched her breast like preening. Gradually he came more closer to her. During this process they either might leap to other branch or take short flight to another tree. Either the male followed the female or vice versa.

On the other hand, when a female approached a male, she would lower her head to touch the male's breast with both her bill and head. He would cross his neck over her neck and she would give submissive posture. During courtship, typical 'swaying twig-grasping' and 'up-down' display (see Kahl, 1971, 1972) were shown by both male and female, however, the former display was mostly shown by the male. The stork perched closely to its partner, would bend its neck downward, point the bill vertically about $<45^\circ$, oscillate from side to side from an imaginary midline four to five times with a gentle pace of half oscillation per second. At each extreme point of every oscillation, sometimes it would pull or touch a twig and give a mild jerk. Both the partners perched side by side, sometimes preened themselves and did up-down display which might be simultaneous or one by one. The bill would be sharply brought down almost touching the breast, or abdomen or feet with a sudden loud nasal 'we-i-nh' immediately followed by throwing the bill upward pointing vertically towards the sky. In this position, they would clatter the bill. The clattering of the bill stopped only after the bill was again brought down below the horizontal. However, during brief bill clattering sequence, the clattering ceased before the bill was brought to horizontal.
(d) Mating and nesting: Usually the courtship display was followed by mating which generally took place either on the nest-branch or in the nest. Only on two occasions mating was seen outside the nesting tree. Just before mating, generally both the partners stood side by side in close contact. The male lifted one of his legs on the back of the female and mounted. He either mounted from the side, or from the front and rear. He would stand on her shoulder for a few seconds and then position himself for copulation. As soon as the male mount on the female she would bend on her 'knees' and give submissive posture, both the wings spread apart for balancing. During copulation the male would flapp wings vigorously and sometimes snap the bill frequently. The bill clattering usually started as soon as he copulated, but sometimes it started simultaneously with mounting. On a few occasions, the sound of the bill clapping was not heard. During copulation the female lowers her open bill <45°, might sway it side to side and give moaning sound. The male usually clasped the female's bill and clattered against her bill. After copulation he stands on her shoulder for some time. Mating was sometimes followed by preening.

The whole process of mating ranged from 11 to 68 seconds (average 25.56 ± 10.38 sec., n = 52). Between a pair mating occurred one to six times a day between 0545 to 1635 hrs. Out of 141 observations, 81 (57.45%) matings occurred in the forenoon, and and 59 (41.84%) in the afternoon. One was seen at mid-day.

Mating was more frequent during the process of nesting and early incubation period. However, four times late mating was seen between a pair in 1995-96 when the age of the first chick was 26, 32, 43 and 45 days.
Simultaneously with mating, nest construction begins. The male would place a green leafy twig on a flat horizontal branch with or without an erect limb. The female steps on it to check it from falling down and soon the base of the nest is formed by piling one twig upon another. During initial stages of nest construction, the female took guard of the nest and most of the nest material was brought by male which could be from the same tree or from other trees in the colony. The GAS did not go outside the colony to bring nest materials, not beyond 200 m. Usually mating occurred after frequent nest material trips by the male. During nest building, the female became more vocal making loud booming sound, accompanied by bill snapping. The male also used to respond by bill clattering when he reached the nest. Both sexes arranged the nest (see section 5.3.4c). They remove leaves from the nest and drop them down as if cleaning the nest (see section 5.3.4c). In the early stages of nest building the male generally roost with his partner in the nest or near the nest. I found the nest construction took 2 to 4 days. Soon after that the female would start spending more and more time on the nest. During this time, egg laying took place. Then the male took care of the nest and relieved the female for longer period.

During the nest construction period, the GAS never left the nest together, but on two occasions the storks were absent in the nest for 11 and 36 minutes to collect nest material.

(e) Incubation: I found that the eggs were laid asynchronously (see section 5.3.7.1 and 5.3.7.2 for clutch size) and the incubation started as soon as the first egg was laid.
The newly laid eggs were chalky white mixed with green sky bluish tinge in colour which became soiled as the incubation proceeded. Both male and female took part in the incubation. During the incubation period (see section 5.3.8 for duration) the incubating stork stood up, preened, flapped and stretched wings, rearranged and repaired the nest, rotated the egg(s) and protected the nest from other storks and birds. When the GAS would stand up after a long incubation bout, it would shake its body stretch neck forward with open bill slightly down the horizontal and would change its orientation in the next phase of incubation. It rotated the eggs to different positions either by grasping with its bill or putting the tip of the bill beneath the eggs and shovelled them towards its feet. During this process, it would put weight on its feet so that the whole nest gets a jerk that lead to roll the eggs to the depression in the central part of the nest.

Though usually parents did not leave the nest unguarded with eggs, I found in three different pairs that left the nest for 3, 3 and 11 minutes to collect nest material. (The GAS collects nest material throughout the breeding season. See section 5.3.6.2).

5.3.3.2 POST-CHICK HATCHING PERIOD

(a) Growth of chicks and associated behaviour of parents

The growth rate of chick was different in different nests. However, a general pattern of growth and behaviour of chick is described below.

The chicks hatched asynchronously with one or two days interval. The newly born chick is about 10 cm long, with pale yellow beak slightly curved downward, blackish large
Plate 4a. The egg arrangement by one of the parents. Note the shoveling bill and bent legs.

Plate 4b. A stork arriving to relieve its incubating partner. Another stork is standing on the nest.
head and neck with yellow patches. Dorsally the body has bluish-black down feathers and the under part is pink. The eyes are large and black, the swollen eyelids are blackish, while the forehead is sky-bluish in colour. It grows fast in the early period and within a week doubled in size with white down feathers almost covering the back.

When a chick hatches, a parent stands with apart legs and tend the baby frequently. This behaviour and posture of the parent is one of the indicators that a chick has hatched. The chick starts making feeble sound which becomes louder into chittering gradually with the age. Both parents feed the young. The parent would regurgitate food on the floor of the nest and chicks would pick it. Soon after hatching, parent started regurgitating black, granular half digested contents so that the hatchlings could feed on them easily. The feeding frequency by regurgitation was high in the early stage of the chicks which gradually declined as they grow old. Initially the chicks could not consume all the food brought to them at a time; the excess were re-ingested by the parent only to be regurgitated later on. While re-ingesting the parent pressed the large size food between its upper and lower mandible to soften and crush it into smaller pieces so that the chicks could devour them. I found that although the parent would not feed the young bill to bill, it would help them by holding food in front in such a way that chicks can easily swallow the food item. The chick would jerk the food, toss its head forward and backward quickly and swallow the food. The chicks were found to be voracious feeders right from hatching. Even one day old chick tried to swallow a frog, much larger than its head. A three day old chick gulped a fish which was larger than its body length; for some time the tail of the fish protruded out side its bill. During the first
week of their life, the chicks spent most of the time sleeping. They also started to crawl on the nest.

At two weeks white down feathers completely covered the body of chick, however the under part was still pinkish. By this time the yellow patches on the head almost disappear. The eyelids become whitish. The forehead or shield turn to white with black spots over it. Dark black pigments spread over the cheek. The ventral side of the throat is covered with dark black pigments continuously like longitudinal bands. Dorsally the neck is greyish and the shoulder is black. On the head and neck erected grey and white hair grow. The ill developed sky-bluish pouch could be distinguished. Beneath the arms and near the flanks black feathers developed. The legs and toes become pinkish in colour.

Generally parent used to relieve each other after more than 24 hrs. The reliever brought food for chick(s) once a day. For about two weeks, most of the time of the parents was spent in brooding the chicks. After that, most of the time was spent in standing and guarding the chicks. However, in the morning and evening, and during rain they brooded and sometimes reclined with the young. The parent also provided shadow to the chick(s) by stretching wings or standing against the sun.

Three weeks old chick is fully covered with snow white foamy feathers except few parts on the ventral side. The bill is pale yellow; at the base of it and on the cheek there are black marks. Black hair are seen hanging from the tip of the pouch and on the
shoulder. The pupil of the eyes is black and the iris is brown. The legs become pinkish white.

Four weeks old chick is about one foot in height. The shield is still white with black spots. The grey and black crested thick hair grow longer. Down the throat, ventrally black longitudinal patches are prominent. Black feathers grew on the 'arms' and hand of the wings. The tail is developed with black feathers surrounding the ridge.

Now it can stand on its feet and flap the wings four or five times at a stretch. The wing span is approximately two feet. It can also walk in the nest. In the early chick stage, the parents hardly left the chick(s) unguarded. However, when the chicks are four weeks old, the parents gradually start leaving the nest, initially for very short duration. When the parent bring food, the young ones perform typical begging display. They drop down to their tarsi opposite to each other (if more than one young), wings half folded, slightly lifted upward, body bent forward, tail cocked and would toss head up and down in rhythmic 'yes' nods with open bill and nasal 'honk-honk' sound.

In a five weeks old chick the primary feathers of the wings start developing. In the initial stage, they have black tip and bluish rachis. The primaries at the tip of the wings are now larger, about one and half inch. The tail feathers become more prominent. The pinkish white legs turn whitish. The longitudinal black patches down the ventral part of the throat now become concentrated only on the pouch. The ear opening surrounded by white mark could be seen.
At this stage the chick tries to leap in the air. Flapping of the wings became frequent. It was found to defecate walking back at the rim of the nest. It could also swallow food very fast.

A six weeks old chick is fully covered by thick down which has changed from snowy white to dirty white in colour. The black spots on the shield are almost gone. The sky-bluish throat pouch become elongated with pink tinge at the base, and black pigments are found sporadically. The black hair hanging from the pouch become longer. Black feather on the shoulder around either side of the base of the neck turn brownish and grow down below to meet at the breast forming a necklace like band. The wings develop four layers of feathers: the lower most black primaries are concealed by broad brownish band of greater secondary coverts, and another two black layers are above the second layer. Twelve broom shaped fan feathers grow at the tail, each of which has a sky-bluish rachis, black horse-shoe shaped flat feathers at the tip followed by thin grey hair hanging from it.

At this stage, the chick is able to defend itself and the parents started to be away from the nest at night. It was even seen to threaten a flying crow or a hovering kite overhead by poking towards the intruder, with a harsh ‘khll-o-ck’ sound. When other GAS come near the nest, it would sit down on its tarsi facing the intruder with half folded wings, and would toss the head up and down, emitting nasal ‘khll-i-ck khll-i-ck’ sound rhythmically with the movement of the head till the GAS flies off. At this stage, I found that the chicks had started cleaning the nest, the same way as the parents do.
Plate 5a. Two nests of the Greater Adjutant Stork in 1996-97 breeding season. The parent is about to regurgitate food (left nest) and the chicks have taken their position. Note the semi-urban habitat in the background.

Plate 5b. The unguarded juveniles on the nest (left). The parent has brought a piece of meat for the juvenile (right).
By seven weeks another row of black feathers are developed just above the fourth layer on the wings. Two longitudinal rows of black feathers grow on either side of the midline of the mantle. When wings are folded, three fourth of the upper parts is covered by black feathers.

Now the parents start coming to the nest only to feed the chick(s); most of the time they were outside the nest. The chick flapped wings more frequently 10 to 12 times at a stretch.

In an eight week old chick, six rows of black feathers appear on the wing. The tail fan become elongated and expanded. While flapping wings, the chick would try to uplift itself in the air.

Throughout the chick stage parents occasionally nursed the chick. During early chick period they gently touched the head and body of the chick. As the chick grew they preened through thick hair over the body of the chick.

(b) Growth of Juvenile and associated parental behaviour

The nine weeks old young attain juvenile stage. It is almost equal to its mother’s height. The upper part is fully covered with black feathers. The brown broad layer of the secondary coverts are more distinct. The shield is white with very few black spots on it. The bill is pale yellow in colour. The ear opening surrounded by white mark is more prominent. The pupil of the eyes is black and the iris is brown. Near the eyes and on
Plate 6a. A juvenile is swallowing intestinal part of a cattle. (Photo: Prasanta K. Bardoloi).

Plate 6b. Two domesticated ducks brought to the nest by Greater Adjutant Stork.
the cheek, black spots are sporadically present. The thick crested black and grey hair on the crown and neck are longer, so are the hair at the tip of the whitish pouch. The legs are creamish white.

At this stage the juvenile is supplemented with pieces of meat and intestinal parts of animal in addition to the fish, amphibians, reptiles and birds. Gradually it start leaping in the air straight upward three to four feet with vigorously flapping wings. The leaping is seen more when the wind is blowin. At about four months of age, the juvenile flies from one branch to another and then to the other trees in the colony. It could chase other intruders from its nest. Sometimes it flew outside the colony and came back to the nest to be fed by the parents. It can also be seen on other nests in search of food and nest material. The visit of the parents to the nest also was irregular in the later part of the post flying juvenile stage. The juvenile was fed by the parents till the fledging (see section 5.3.7 for fledging period). The juvenile fledged asynchronously; not necessarily the older sibling would leave earlier.

5.3.4 SOME OTHER BREEDING BEHAVIOUR

Greeting display: As has been described in the section 5.3.3.1 c, greeting display between a pair of GAS commences soon after the pair formation. It gradually declines by the time the chicks reach juvenile stage because the parents hardly come to the nest at the same time. Among the greeting display, the up-down display and bill clattering were more common. Usually when a partner arrives at the nest, the other partner greets it by upward bill clattering. Then both show up-down display. Each stork
could recognise its partner from a long distance. When nest material was brought by
the male, generally he uttered a low pitched ‘kis-kis’ sound with one second pause after
each ‘kis’. On the other hand, generally the female brought nest material with nasal
‘we-i-nh we-i-nh’ sound. The female greeted the male by her long typical squeal in the
early part of the breeding season. Side to side swaying of the bill was also seen as part
of the greeting display. When a female arrives on the nest, the male sway the bill side
to side, bowing down his head with typical ‘kis-kis’ sound; on the other hand, when a
male reaches the nest, the female sway the downward pointing bill side to side and
places the nest sticks in accordance to the movement of the bill. Downward short
duration bill clattering was also seen to greet each other. However, sometimes arrival of
one partner to the nest was not accompanied by greeting display.

(a) Aggression: As has been described in the section 5.3.3.1 b, agonistic behaviour of
the GAS was more in the beginning of the breeding season which gradually decreased.
However, the aggressiveness varied according to the individual and situation of its
surroundings. Generally female appeared to be more aggressive. Storks were found to
chase other storks which approached near their nest sometimes leaving behind even
unprotected nest with egg(s) or chick(s). A stork could chase another stork up to 100 m,
during which it flies with stretched neck and snap the bill loudly. Loud bill clattering was
not only greeting display but also a threat to the other stork. However, sometimes a
breeding stork was found to tolerate the presence of other storks and even crows very
near to its nest.
Plate 7a. One dead juvenile is hanging from the nest. The other juvenile is sitting on the nest.

Plate 7b. A dead juvenile with a deformed wing.
In the early part of the breeding season, some storks try to invade other nests for occupation or to replace a partner from an established pair. A case of nest invasion occurred in the first breeding season when nest of one pair was occupied by another pair. Once, a stork was also found to snatch away food from other stork's nest. During fight they would poke at each other's head in quick succession. Post flying juveniles were also found to be aggressive towards other adult storks which try to enter their nest.

(b) Nest arrangement: Storks were found to repair, rearrange and clean their nest throughout the season which however, decreased as the young grow up. The GAS cleaned the nest by removing egg shell and decomposed old leaves from the interior part of the nest. It would pick up old leaves by inserting one third of its bill with frequent pecking and throw them outside the nest. It would arrange the nest by grasping sticks and placing them with inward and outward pull and push at the rim of the nest. I found that GAS took great interest in maintenance of the nest. They would place and rearrange sticks all along the nest rim and also at the bottom. It takes turn slowly to place the sticks on the periphery of the nest in a circular way. While doing so, it put weight on one leg to another alternately standing at the centre, so that a shallow depression was developed at the centre of the nest. Sometimes nest arrangement continues for more than half an hour.

(c) Nest material stealing: I observed that whenever storks found an unguarded nest or a vacated nest they stole nest materials for their own nest. Even a five months old
Plate 8a. Begging posture of a juvenile. Note the deteriorating nest. (Photo: Prasanta K. Bardoloi).

Plate 8b. The post-flying juveniles. Note the defoliated nesting trees. (Photo: Prasanta K. Bardoloi).
juvenile would steal the nest sticks from empty nests. Sometimes a stork would even rob nest material in the presence of its adult or young owner.

(d) Father-offspring mating behaviour: I observed this peculiar behaviour of a male stork in one nest each in both breeding seasons. The male who was attending the nest, suddenly stepped one leg on the back of one of his young and mounted it. He stood on the back of the young for 12 to 20 seconds and came down. Some times he also acted like copulating with the young with or without mild bill clattering. During these acts the young uttered harsh chittering. In the first breeding season I found this behaviour ten times when the young was nine to eleven weeks old. In the second breeding season this behaviour was seen twice when the young ones werer 38 and 61 days old.

5.3.5. PARENTAL INVESTMENT

5.3.5.1. ACTIVITIES BY PARENT STORKS ACCORDING TO YOUNG AGE

The percent time spent on different activities by male and female parent in each breeding season separately are shown in Figs. 5.3a, 53.b, 5.4a, 5.4b. On each nest there were two and one young in the first and second breeding season respectively.

Incubation: Out of the total observation duration of 613 h, in the first breeding season, only 36 h. of later part of the incubation period before hatching of the first chick was studied. Next year, out of the 626 h of observation, 69 h of the later incubation period could be studied. In the first breeding season, before hatching of the first chick both sexes incubated for about 76% (male 50% and female 26%) of day light. But in
Fig. 5.3a Percentage time spent on different activities by male GAS according to the age of the oldest chick (1995-1996)

* 100 days old young were not observed

Fig. 5.3b Percentage time spent on different activities by female GAS according to the age of the oldest chick (1995-1996)

* 100 days old young were not observed
Fig. 5.4a Percentage time spent on different activities by male GAS according to the age of the oldest young (1996-1997)

* 70 days old young were not observed

Fig. 5.4b Percentage time spent on different activities by female GAS according to the age of the oldest young (1996-1997)

* 70 days old young were not observed
the first breeding season, the male incubated about 26% and the female incubated about 40% out of total 66% of day light incubation (Figs. 5.3a & b and 5.4a & b). During the post hatching period, incubation continued till hatching or abandoning of the last egg of the clutch. In 1995-96 in one nest incubation was seen till the first chick was 30 days old after which the infertile egg of the clutch was dropped. On the other hand, in 1996-97 breeding season, in one nest incubation was noticed till the first hatched chick was 10 days old. As the chicks grew, the duration of incubation percentage gradually declined.

Reclining: This activity (Sitting in reclining posture to give warmth to the young) was found to be of very short duration and it depended on weather condition. I found that 1995-96 which was a comparatively warmer season, reclining was seen till the young-age of 60 days. While next year, it was seen till the juvenile age of 80 days. This was mainly because the 1995-96 was a colder season.

Standing: GAS spent most of the time standing in the nest. This activity increased with the age of the young till the young attained juvenile stage. In the later part of the juvenile stage maximum nest attendance was seen while standing. In the post flying juvenile stage, this activity declined very fast.

Wing stretching: Wing stretching is done by parents to give shade to chicks. This activity was also of very short duration, it lasted two to three minutes only. In the first breeding season (1995-96) which was warmer, it was seen till the chicks had reached
the age of 30 days. While next year, this activity was not seen at all. This was mainly due to colder weather in 1996-97.

**Nursing:** Different degrees of nursing was seen in different nests. For instance, in 1995-96, it was very rare in the intensively studied nest, while in the second breeding season (1996-97) both the parents showed this activity till the young ones were 80 days old.

**Nest arrangement:** This activity was found throughout the breeding season, except the last few days of parental care. The time spent in nest arrangement was more or less similar in both the years and in all the nests.

**Re-ingestion:** This activity was seen in the early chick stage. The GAS did not spend much time in this activity.

**Absence:** Alternately both male and female were absent from the nest from the beginning of the observation. However, duration of absence increased gradually with the age of the young. In the later part of the season, parent were absent almost 100% of the day time.
5.3.5.2 ACTIVITIES BY PARENT STORKS AT DIFFERENT TIME OF THE DAY

Graphical representation of the percentage time spent on different activities by parents on the nest at different time of the day is shown in figs. 5.5a & 5.5b and 5.6a & 5.6b.

In both the breeding seasons it was clearly seen that the GAS incubated more during the cold hours of the day: morning and evening. On the other hand, storks were found standing more during mid-day. Wing stretching was also more at noon while reclining was found more in the morning and evening. The GAS spent almost equal duration of time for nest arrangement and nursing the young. Re-ingestion of food generally occurred during mid-day and afternoon.

5.3.6 DIFFERENT TYPES OF TRIPS

5.3.6.1 Total number of trips according to young age

Among the four types of trips made by GAS recorded in the first breeding season (n = 59 days), nest material trip was the largest in number (Fig. 5.7a). Collectively both parents made 262 nest material trips, followed by miscellaneous trips (99), foraging trips (84) and water trips (3).

Except the water trips, the other three types of trips were recorded in the second breeding season (n = 58 days) among which nest material trips were again largest in number (5.7b). The parents made 94 nest material trips, 66 foraging trips and 54 miscellaneous trips. In comparison to the first breeding season, number of trips were less in the second breeding season (see discussion).
Fig. 5.5a Percentage time spent on different activities by male GAS in nest according to time of the day (1995-96)

Time of day (hrs)

Fig. 5.5b Percentage time spent on different activities by female GAS in nest according to time of the day (1995-96)

Time of day (hrs)
Fig. 5.6a Percentage time spent on different activities by male GAS in nest according to time of the day (1996-97)

Fig. 5.6b Percentage time spent on different activities by female GAS in nest according to time of the day (1996-97)
In both the seasons, female brought more nest materials than male, while male made more foraging trip than female. During 1995-96 season, almost equal miscellaneous trips were done by both the partners, while during 1996-97, female was found to make more miscellaneous trips.

5.3.6.2 Frequency of different trips according to the 'young-age'

(a) Nest material trip: The average number of trips by parents together per day in the first breeding season increased till the two young ones were 60 days old (Fig. 5.8a). Nest material trips stopped when the young ones were 90 days old.

In the second breeding season (1996-97), the peak of the frequency was found when the young one was 50 days old. However, there was little fluctuation in the frequency in the early stage of the young. These trips stopped when the young one was 100 days old.

(b) Foraging trip: In the first breeding season, the frequency of the foraging trips increased till the young ones were 60 days old, and then gradually decreased. In the second breeding season the frequency reached a peak when the young attained the age of 100 days.

(c) Water trip: This trip was very rare and was observed only in the first breeding season when the young were 40 and 50 days old.
Fig. 5.7a Different types of trips by parent GAS throughout the breeding season 1995-1996

\[ n = 59 \text{ days} \]

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Fig. 5.7b Different types of trips by parent GAS throughout the breeding season 1996-1997

\[ n = 58 \text{ days} \]

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Fig. 5.8a Frequency of different types of trips nest by both parent GAS according to the age of the oldest young (1995-1996)

* 100 days old young were not observed

Fig. 5.8b Frequency of different types of trips by both parent GAS according to the age of the oldest young (1996-1997)

* 70 days old young were not observed
(d) Miscellaneous trip: This was seen throughout the observation period in the first breeding season. The frequency was highest at the chick age of 50 days. In the second breeding season this trip was not found after the young was 120 days old. The frequency was highest when the chick was 10 days old.

5.3.6.3 Different types of trips according to time of the day

In both breeding seasons, nest material trips and foraging trips were more frequent in the middle part of the day (Figs. 5.9a & b). Miscellaneous trips were more at noon in the first breeding season, while it was more in the morning in the next season. The water trip was not made at noon.

5.3.7 REPRODUCTIVE SUCCESS

The breeding records of the Greater Adjutant Storks in the North Haibargaon colony in two successive breeding seasons are presented in detail in Appendices 5.1 and 5.2.

5.3.7.1 FIRST BREEDING SEASON (1995-96)

Forty eight nesting attempts were made on 19 trees among which two failed in the very beginning of nest building, three re-nesting occurred and 16 nests were abandoned. The earliest nesting attempt was made on 7 September 1995 and the last was made as late as on 25 December 1995. A total of 43 nests (in which incubation was started; see section 5.2.6) were built on 19 nesting trees. The earliest and the last nest was built on 7 September 1995 and 28 December 1995 respectively.
Fig. 5.9a Different types of trips by parent GAS according to time of the day (1995-1996)

Fig. 5.9b Different types of trips by parent GAS according to time of the day (1996-1997)
Out of 43 nests, 31 were successful to produce at least one hatchling. The nesting success was 72.09%. The chick hatched as early as 30 October 1995 and as late as 18 January 1996. The average clutch size was $2 \pm 0.77$ s. d. ($n = 31$) eggs per nest with two-eggs clutch was more frequent (51.61%). The largest clutch size was four in one nest in the first breeding season. Sixty one chicks hatched of which 51 (83.61%) fledged and nine (14.74%) died. One chick which had dropped from the nest was rescued and released later. The earliest and the latest date of fledging from the colony was 28 February 1996 and 6 May 1996 respectively. The fledging success of the whole colony was $1.19 \pm 1.03$ s. d. ($n = 43$) young per nest. Considering only the successful nests the fledging success was $1.65 \pm 0.84$ s. d. ($n = 31$).

5.3.7.2 SECOND BREEDING SEASON (1996-97)

Forty six nesting attempts were made on 14 trees among which two failed in the very early stage of nest building, four re-nesting occurred and 23 nests were abandoned. The earliest nesting attempt was made on 12 September 1996 and the latest was made as late as on 22 December 1997. A total of 40 nests were built on 12 nesting trees. The earliest and the last nest was built on 6 October 1996 and 27 December 1996 respectively.

Out of 40 nests, 19 were successful to produce at least one hatchling. The nesting success was 47.5%. The chick hatched as early as 2 November 1996 and as late as 24 January 1997. The average clutch size was $1.74 \pm 0.65$ s. d. ($n = 19$) eggs per nest with two-eggs clutch was more frequent (57.89%). Thirty two chicks hatched of which
21 (65.63%) fledged and nine (28.13%) died. Two chicks which had dropped from the nest were rescued and released later. Three cases of probable re-egg laying (7.5%) occurred. The earliest and the last date of fledging from the colony was 13 March 1997 and 26 May 1997 respectively. The fledging success of the whole colony was $0.53 \pm 0.78$ s. d. ($n = 40$) young per nest. The fledging success of only the successful nests was $1.11 \pm 0.81$ ($n = 19$).

The average clutch size of both seasons was $1.9 \pm 0.74$ s. d. ($n = 50$). The fledging success of both seasons in the entire colony was $0.87 \pm 0.97$ s. d. ($n = 83$) and that of successful nests was $1.44 \pm 0.86$ s. d. ($n = 50$). Combining both season's data, 72 young fledged out of 93 hatchlings giving a overall fledging success 77.42%.

5.3.7.3 YOUNG MORTALITY IN EARLY AND LATE BREEDING

It was seen that in both the breeding seasons, nesting took place from September to December. I categorised the GAS those that built their nests in September and October as early breeders and those that built their nests in November and December as late breeders.

Among the successful nests built in the first breeding season, 82.76% were built in the early breeding period and remaining 17.24% were built in the late breeding period. Out of 51 chicks hatched in the early breeding period, only two young (4%) died, while in the late breeding period seven young (70%) died out of 10 hatchlings produced. Out of nine death occurred in the first breeding season, 22.22% was recorded in the early breeding period and 77.78% was in the late breeding period.
In the second breeding season, among the successful nests, 58% were built in the early breeding period and 42.11% were built in the late breeding period. Twenty two hatchlings were produced in the early breeding period of which four (18.18%) died. Five chicks (50%) died out of 10 hatched in the late breeding period. Among the nine young ones death in the second breeding season, 44.44% died in the early breeding period and 55.56% in the late breeding period.

5.3.8 INCUBATION AND FLEDGING PERIOD

The incubation period of the Greater Adjutant Stork was found to be about 40 days and the fledging period was about 140 days (Table 5.1). There was no significant difference of incubation and fledging period between two successive breeding seasons. However, the range varied markedly among different pairs and different fledglings. The shortest incubation period was 30 days and the longest was 55 days in the colony. The fledging period ranged between 96 to 173 days in the first breeding season and 110 to 197 days in the second breeding season. However, the more accurate incubation period was calculated as 34.6 ± 2.70 s. d. days, n = 5 (see section, 5.2.7 for method).
5.4 DISCUSSION

5.4.1 CHRONOLOGY

The Greater Adjutant Storks arrive at the North Haibargaon breeding colony just after the monsoon, when the dry season has began. In both breeding seasons the timing of the arrival was same which suggests that GAS follow a definite time frame for breeding. The timing of GAS nesting period synchronised with the reducing water level (Saikia and Bhattacharjee, 1996a; Bhattacharjee and Saikia, 1996). My observation also agrees with theirs. As has been described in section 2.4 (c), there is heavy rainfall during monsoon from June to September in Assam. From September onwards water level gradually recedes with the decreasing rainfall. This period also coincides with the increase of the prey species. Many species of fish and frog breed during monsoon. Their population increases and they spread over in inundated low lying areas. When water level goes down they concentrate in drying up pools and puddles and become easy prey for wading birds.

Most bird species breed around the time when food supplies for themselves and their young are most readily available (Thompson, 1950). Heinzman and Heinzman (1965) also consider food availability as an important factor in initiation of the breeding season in Wood Stork. Lack (1954, 1968) suggested that breeding is timed in relation to the availability of food for the young, which was modified by Perrins and Birkhead (1983). According to them, the availability of food for the growing young is the ultimate factor; while day length is the proximate factor for timing of breeding. Egg formation needs minimum three weeks in birds. Food availability at the time of egg formation can affect
the timing of breeding. Therefore, well ahead of the hatching of chick(s) the bird has to synchronise its timing of egg formation with the food abundance. Though the major ultimate factor in determining the breeding season is food supply (Ford, 1989), the most important proximate factor is the seasonal change in length of the day which stimulates, via neurohypothalamic pathways, endocrine secretion that allow the gonads to assume a functional state (Murton and Westood, 1977). Desai et al. (1977) showed that the correlation between the testes and breeding cycle of the Painted Stork *Myctena lecocephala* was obvious. Pomeroy (1978b) also states about the possibility of an intrinsic (circannual) rhythm for time of nesting in Marabou Stork *Leptoptilos crumeniferus*. Therefore, both ultimate as well as proximate factors - food supply and seasonal change with shorter days correspond to initiate breeding of GAS in North Haibargaon breeding colony.

In congeneric Marabou Stork, breeding usually begins in dry season and ends in rains (Brown *et al.*, 1982). The relationship between nesting and rainfall suggests that some rain, but not too much, increases the Marabous food supply (Pomeroy, 1978b). Breeding season of Marabou vary geographically in eastern Africa (Pomeroy, 1978c). He further opines (Pomeroy, 1986) that it seems to be declining rainfall rather than the actual amount of rain which stimulates breeding at these sites. The American Wood Stork *Myctena americana* initiates nesting when water level goes down (Kahl, 1964). Seasonal rains strongly influences the beginning of nesting in Maguari Stork *Ciconia maguari* (Thomas, 1985). All other breeding storks in India, Painted Stork, Whitenecked Stork *Ciconia episcopus*, Blacknecked Stork *Ephippiorhynchus asiaticus*,

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The population trend throughout the breeding season in both years of my study suggests that as the breeding season progresses the GAS start leaving the colony. The unsuccessful storks who could not build nests, leave the colony and the parent storks also do not spend much time in the colony when the young grow up (in the later part of the season). Though in the first season data of September and October were not available, in the second breeding season it was seen that the number of storks reached a peak in October when almost all breeding storks had arrived in the colony. In both seasons there was a smaller population peak in December. This could be due to the late breeders who returned to the colony. Similar second smaller peak was seen in a Painted Stork colony by Urfi, 1993 which he could not explain but guessed that this peak could be due to second breeding attempt or because of prolong breeding effort. In Maguari Stork also late-arriving storks begin to build nests, well after the beginning of the breeding season (Thomas, 1986).

The reason of counting less number of storks in the morning than in the evening is probably because, some storks leave very early for foraging but all members of a colony gather in the evening for roosting. Moreover, I could also study the storks till very late in the evening.
5.4.2 GENERAL BREEDING BIOLOGY

5.4. 2.1 External morphological changes

The external morphological changes in GAS during breeding season was similar to the observation of Saikia and Bhattacharjee (1996a) and Bhattacharjee and Saikia (1996). Similar changes occur in Marabou Stork also (Brown et al., 1982). Pomeroy (1977b) has described six different types of plumage of Marabou Stork which appear according to the age of the bird and seasonal changes. He also measured them and found that males were considerably larger than females which I found in GAS also. This was earlier reported by Kahl (1972). In Painted Stork (Desai et al., 1977) and American Wood Stork *Mycteria americana* (Kahl, 1962) males are larger than females.

Contrary to the common observation, I found female GAS were more brighter than males. It has not been reported earlier. At the start of the breeding season, the males of all storks typically establish themselves on a potential nest site and the females approach to established males (Kahl, 1971). In GAS, I found that often a second female moved around an established pair. The competition for pair formation, thus was between females. Mckilligan (1991) reported a possible bigyny found in Intermediate egret *Egreta intermedia* where a nest was attended by one male and two females. However, only the male and the primary female incubated and remained together past incubation. It was also proved when a dull coloured GAS male, not even having typical breeding plumage, paired with a brighter female and successfully raised young. This type of distinction between the sexes however, was very temporary and it was seen in the early part of the breeding season only.
5.4.2.2 Crowding and aggressive behaviour

Sub-adult birds may occupy and defend nest sites and sometimes form temporary pairs without breeding (Hornberger, 1967). Lack (1968) also observed that in some colonial species, the sub-adults also come to the breeding places, form pairs, occupy nesting sites and build nests, but without proceeding further. I found some sub-adults and smaller ‘new adults’ to arrive in the colony. Bhattacharjee and Saikia (1996) also observed that both sub-adults and non-breeding GAS also came to the nesting colony, but Pomeroy (1977c) observed that it does not necessarily follow that all storks having breeding plumage are sexually mature. The minimum age at first breeding is four year in Marabou Stork (Pomeroy, 1977b) and three year old male and four year old female in Maguari Stork (Thomas, 1984b). According to Bhattacharjee and Saikia (1996), GAS and Lesser Adjutant Stork become sexually mature at the age of three to four years. Lack (1968) has explained the arrival of the sub-adults to the breeding colony as the preparatory year to learn the best feeding areas around their nest without the strain of finding food for a brood.

Bhattacharjee and Saikia (1996) reported that in the early part of the breeding, rigorous vocalization and 14 to 16 storks flying together from one tree to another was seen which is similar to the behaviour what I have called as ‘crowding’. Coulter (1989b) has termed the aggressive interactions in American Wood Stork as ‘mobblings’ and Kahl (1972b) has referred these as “bachelor parties”. Although aggression was always associated with crowding, fight was not between two storks; instead a flock of five to fifteen GAS took part together in this activity. However, territorial aggressive display by
male stork which is a part of crowding has been described by Kahl (1971) and Desai et al. (1977). Same kind of behaviour is seen in Louisiana Heron *Hydranassa tricolor* (Rodgers, JR., 1978), Cattle Egret *Ardeola grayii* (Blaker, 1969), Grey heron *Ardea cinerea* (Milstein et al., 1970) and Great White Egret *Egretta alba* (Tomlinson, 1976). The aggressive interactions of ‘mobbings’ in American Wood Storks were moderately frequent in the early part of the breeding season which rose a peak in the following week correlating with a high number of nest start, and declined gradually (Coulter, 1989b). This observation agrees with my observation on GAS.

Schuz (1944) reported that fighting at nests is frequent among White Storks *Ciconia ciconia* and leads to many deaths. In contrast to Thomas (1986) observation that attacking Maguari Storks were mostly males, I observed in GAS that aggressiveness varied individually, female storks seemed to be more aggressive. Though Coulter (1989b) opined that female American Wood Storks are generally less able to defend themselves, I found in GAS that, females were even invader. As Coulter (1989b) recorded nest invasion in American Wood Stork, I found same case in GAS too. The replacement of one incubating female American Wood Stork by another pair and throwing out the former’s egg seen by him was similar in GAS also, but the aggressor was a female. Moreover, while guarding a nest with eggs or chicks, a female GAS sometimes chased away other GAS near the nest, leaving the nest unguarded. Such behaviour was not seen by Coulter (1989b) in American Wood Storks. The degree of aggressiveness perhaps depends on individual’s “mood”, that is why sometimes the GAS tolerated presence of a stork or a crow very near to the nest, while at other times.
the same GAS chased away stork which was perching 60 m. from its nest. Coulter (1989b) found that unguarded chicks were thrown out by neighbouring storks. I also found the same case in GAS. While pulling nest sticks from the unattended nest the “robber stork” attacked the defending chicks and while doing so, two three-week old chicks fell down from the nest.

The ‘aerial clattering threat’ described by Kahl (1972a) in Lesser Adjutant and Marabou Storks, and not in GAS, was observed by me in GAS. According to him, Lesser Adjutant remains silent while chasing another stork in the air, but Marabou clatters loudly as the opponent is approached closely. The same behaviour of Marabou Stork was seen in GAS.

The other hostile display described by Kahl (1972a) such as snap display, pre-flight snap, erect-gape and anxiety stretch - all were noticed in GAS. However, forward poking which is similar to ‘forward display’ behaviour in herons (Meyerriecks, 1960; Tomlinson, 1976) was not mentioned by him. In this behaviour, two GAS stand erect on their nest or branch face to face and poked at each other frequently with sometimes sound of bill snapping hardly giving any physical contact. Sometimes GAS was also seen shooting the bill sharply in horizontal direction in the air when the opponent was slightly at a distance.

5.4.2.3 Pair-formation, courtship and greeting display, mating and nesting
Kahl (1970, 1971, 1974) has vividly presented comparative accounts of breeding behaviour of all storks. All storks show a number of ritualized social displays during the
period of pair-formation and courtship (Kahl, 1971). Courtship is a necessary prelude for mating (Tarburton, 1993). Except some species-specific behaviour, generally almost all storks show similar behaviour. Congeneric species are more homologous in breeding behaviour.

In many respects of morphology and behaviour, the Greater Adjutant resembles its African cousin, the Marabou Stork (Kahl, 1974). On the other hand, the majority of behaviour pattern observed in Lesser Adjutant were closely similar to those of the Greater Adjutant (Kahl, 1970). I saw the same 'swaying twig-grasping' in GAS as described by Kahl (1972a) in GAS and Marabou Stork. Apart from this behaviour another similar behaviour was seen by me that was not described by him: the side to side swaying of the bill by male GAS to greet the female partner at her arrival to the nest with typical "kis-kis" sound can be compared with the 'advertising sway' of Asian Openbill Stork (Kahl, 1971). The only differences are; (a) I did not find GAS lifting its foot one by one with each oscillation; and (b) I heard sound in GAS which was not mentioned in Openbill Stork. However, Kahl (1971) has opined that this behaviour of the Openbill Stork might be a highly developed ritualized variant of the swaying twig-grasping display of the genus *Leptoptilos*.

I saw female GAS also doing the same type of behaviour to greet male GAS in nest by swaying downward pointing bill and arranging nest sticks. This behaviour has not been described earlier. Similar type of 'twig passing display' is seen in Great White Egret *Egretta alba* (Tomlinson, 1976), where the female egret greets the male on his arrival to
the nest by 'stretch display' and after this she stretches her neck out towards the male, grasping a twig in her bill, rearranges into the nest.

The most common greeting display is the up-down display which except in Saddlebill Stork, Kahl (1971) has seen in all storks. He has mentioned that all three species of *Leptoptilos* give frequent up-downs whenever one member of the pair returns to the nest after an absence. But I found that the GAS did not give up-down display every time its partner arrived to the nest. In the first breeding season in one instance, the incubating female did not show any reaction though the male came to the nest three times frequently.

Kahl (1970, 1971, 1972a and 1974) emphasised on the difference between Marabou Storks and two Adjutants in up-down display. In the former species the bill is first thrown upward and vocalizations are given, then the bill is pointed downward and clattered. In latter two species the bill is directed upwards during both vocalizations and clattering. I also observed upward bill clattering in GAS but I would like to stress on the fact that the clattering did not always cease before the bill reached horizontal position; sometimes clattering stopped only after the bill pointed down. Instead I saw on some occasions, member of one pair greeted the other on nest at the latter's arrival by short downward bill clattering. Vocalizations of Lesser Adjutant is hoarser and more rasping than GAS (Kahl, 1970).

There is no available literature regarding mating behaviour in GAS. However, comparing with copulation pattern with other storks in literature it is found that loud
copulation clattering of GAS resembles with other storks except Openbill Stork where the male does not clatter his mandibles loudly together (Kahl, 1970). The balancing posture of the female during copulation is similar with that of other storks except White Stork where the female does not hold her wings widely spread (Kahl, 1971) and Jabiru Stork where the female usually opens its wings fully at first and then closes them partially after the male is in position (Kahl, 1973). The post copulation preening which I noticed occasionally in GAS is also found in Painted Stork (Desai et al., 1977) and Maguari Stork (Thomas, 1986). The copulation duration of GAS (25.56 ± 10.38 sec.) is found to be the longest among storks: 10 sec. in Painted Stork (Desai et al., 1977), 8.77 ± 1.15 sec. in Maguari Stork (Thomas, 1986), 23.8 sec. in Blacknecked Stork and 15.4 sec. in Jabiru Stork (Kahl, 1973). Late mating as I found in GAS is also reported in Painted Stork where copulation was found even after the fledging of the young (Desai et al., 1977). However, copulation posture between the father and one of his young is not reported in other storks. It is however difficult to explain the reason as this was a rare case and not found in every nest.

I found that right from the early morning till the late evening, the GAS mate at various time of the day. Maximum incidents of mating were seen before noon. Thomas (1986) also noted maximum mating in forenoon in Maguari Stork. However, considering the range of mating incidents in a day, it seems merely coincidental. Frequent copulation is seen in Painted Stork also (Desai et al., 1977). Birkhead and Moller (1992) found that high copulation frequencies are a feature of species with male parental care. Patrie (1992) has proposed a hypothesis that repeated copulation may reduce the likelihood that a male partner mates with another female.
Similar to other stork species, the male of the GAS gather most of the nesting materials during the pre-egg laying stage (Bhattacharjee and Saikia, 1996). My observation is similar as theirs. In egrets (Tomlinson, 1976) and herons (Rodgers, JR., 1978) also the male collects more nest material in the initial stage of nest building. Saikia and Bhattacharjee (1996a) reported that after one week of nest building either one or both the partners left the nest for foraging or soaring. Only twice I saw both the parents leaving the nest. In Maguari Stork an interesting phenomenon was found early during nest building when at about 1330 hrs. all storks from the colony departed and did not return until the next morning which Thomas (1986) explained as colony synchronization to keep nests from being vandalized by conspecifics.

5.4.2.4 Development: egg to fledgling

My description of freshly laid eggs of GAS resembles with that of Oates (see Hume and Oates, 1890). The asynchronous laying of eggs in GAS is also reported by Saikia and Bhattacharjee (1996a). Lack (1968) states that in Ciconiiformes, the successive eggs in a clutch are laid two or more days apart, incubation starts with the first egg, and the young hatch one or more days apart. Asynchronous hatching and brood reduction are widespread among predatory birds (O'Connor, 1978). Lack (1954) postulated brood reduction hypothesis which states that during food shortage, youngest sibling dies and the brood size is reduced so that the parents can sufficiently feed the other young. Later, many authors have proposed several hypotheses of which the recent one is sexual-conflict hypothesis by Slagovold and Lifjeld (1989) and Slagovold (1990) in
which they found that there is a positive significant relationship between hatching
asynchrony and sexual size dimorphism.

The development of GAS chick to fledgling stage and associated parental behaviour are more or less similar with other storks. The stork nestlings spend most of their time between meals sleeping and thereby reduces its energy demands (Kahl, 1962). The rapid early growth pattern exhibited by altricial birds adapts them to survive in several ways. A four-week old GAS tried to leap in the air with flapping wings. In comparison to GAS, Marabou chick can stand and flap wings in 17 days (Brown et al., 1982), Maguari chick can stand in 22 days (Thomas, 1984). The postures, movements, and vocalizations in the begging display and nesting defence display of both Adjutant species were quite similar to those Marabou Stork (Kahl, 1972). However in solitary breeding storks, vocalizations of the chicks are not as loud as those given by the colonial species (Kahl, 1973).

Walking backward for defecation at the edge of the nest by a five-week old GAS was seen by me. This is also seen in Maguari Stork (Thomas, 1984) from four-week onwards. The wing exercise is started in Whitenecked Stork in 33 days (Scott, 1975) and 25-30 days in Painted Stork (Desai et al., 1977). Saikia and Bhattacharjee (1996a) also reported about the jumping of the chicks on the nest platform but have not mentioned the age of the young.

As soon as the nestlings are strong enough to defend themselves, parents start leaving them unguarded for progressively larger period of time. However, I found that from the
age of six-week, the GAS started leaving the chicks; sometimes even at night. The chick could defend itself and tried to poke at flying crow; which was similar to the behaviour of Lesser Adjutant nestlings at this age as described by Kahl (1972). The storks leave the nestlings unguarded from the age of six weeks in Maguari Stork (Thomas, 1984; 1986), three to four weeks in Painted Stork (Desai et al., 1977), 33 days in Whitenecked Storks (Scott, 1975) and three weeks in American wood Stork (Kahl, 1962; 1972b); but six weeks as observed by Clark (1972). Coulter (1989b) observed that there was usually one parent at the nest until the chicks were between 21 and 30 days old.

The GAS juvenile started hopping from one branch to another at the age of about 100 days and after one or two week it started flying but still roosted in the colony. This behaviour is found in other stork species. The young Marabou Storks hover over nest at 65 days, make short flight over trees at 95 days and at 95-115 days they make first flight (Brown et al., 1982). In comparison to these two congeneric species other storks take shorter time to first flight. It takes about two months in American Wood Stork (Kahl, 1962; 1972b, and Clark, 1972), 55 days in Whitenecked Stork (Scott, 1975), 67 days in Maguari Stork (Thomas, 1984; 1986) and 60-70 days in Painted Stork (Desai et al., 1977). I found juveniles were aggressive to juveniles of other nests and other adult storks when they tried to visit their nest, but in American Wood Stork, Coulter (1989b) saw juveniles were fed on nests that were not their own.
5.4.2.5 Parental Investment

Biparental care occurs in over 90% of bird species (Wesoeowski, 1994). In the GAS also, both male and female take part almost equally to raise the young. Marabou Stork incubates about 84% of day light sharing 48% and 36% between male and female respectively (Brown et al., 1982). Coulter (1989b) found that during the courtship and incubation periods male American Wood Stork spent slightly more time at the nest than female. The Painted Stork female shoulders major responsibility in incubation (Desai et al., 1977). But in GAS it seems that there is no fixed rules which sex incubates more. For example, in the first breeding season (1995-96) male was found to incubate for more time than the female, but in the next season it was opposite. However, because of the unavailability of total incubation data (from day one) no conclusion should be drawn.

In the first breeding season incubation was seen till the first chick was 30 days old because there was a third egg which not hatched (see section 5.4.3 for prolong incubation period). However, as I mentioned in section 5.2.4 brooding was also included with the ‘incubation’ seen for 10 days after hatching of first chick in the second breeding season, it was mainly brooding. Saikia and Bhattacharjee (1996a) state that a clutch of two to three eggs of GAS needs six to seven days to complete. Therefore, in 1996-97 though I could not see all the eggs, and only one chick was seen later, the GAS might be brooding after the hatching of the first chick.

Incubation along with brooding, and reclining are the activities to give warmth to egg(s) and young. Hence it was obvious to see these activities during the cool hours of the
day. On the other hand, wing-stretching to shade the chick(s) was seen mainly during mid-day. This activity is required only in the early chick stage and that is why it was seen up to 30 days old chick stage. Compared to 1995-96, wing stretching was rarely seen in 1996-97 mainly because the later breeding season was colder than the former. However, duration of wing-stretching was very short and most of the shading was done by parents standing against the sun. On sunny days the GAS showed wing-stretching in the foraging habitat also, and it seems this was a social behaviour triggered by imitating each other in the flock.

As the chicks grow and develop feathers, they do not require brooding from parents but they are still vulnerable to predators and heat, so the parents guard them by standing and remaining on the nest for prolong periods. Therefore, standing activity increases after the chicks are six weeks old.

I found that nursing by parental allopreening varied among different parents. Allopreening by parents was seen more in the one-chick brood than two or three clutch broods. The reason could be that in the absence of parents, siblings could preen each other in the nest if there were more than one chick. So the single chick required more preening from parents.

I found that nest arrangement was not necessarily done only after the bringing the nest material. The GAS used to rearrange already existing nest material as and when required. I saw nest cleaning activity from the very beginning of nest building and though rare, it was seen in the post flying juvenile stage also. Thomas (1986) observed
in some pairs of Maguari Storks, nest material was added to disintegrating nests after their young had fledged. Chicks learnt this behaviour from the parents or it could be an innate behaviour.

Saikia and Bhattacharjee (1996a) and Desai et al. (1977) reported that storks collect nest material from ground which I did not see in GAS. Though I found during the early part of nest building, most of the nest materials were collected by male, in the long run, it was found that throughout the breeding season female brought more nest material than male. My result is at variance with that of Coulter (1989b), Desai et al. (1977) and Tomlinson (1976) in American Wood Stork, Painted Stork and Great White Egret respectively.

I saw most of the nest material trips were done in the middle part of the day. Usually when one partner relieved the other at mid-day, the reliever took guard of the nest and the out going partner made few nest material trips before it finally left for the day. So during the exchange of nest attendance, most of the nest sticks were collected and this time was generally between 1000 to 1400 hrs (Figs. 5.9 & b).

Saikia and Bhattacharjee (1996a) observed that the intensity of carrying nest material to the nest was high during pre-egg-laying and pre-hatching period and then decreased abruptly. But the frequency of nest material collection again increased when the chicks grow and start jumping on the nest platform. Their observation agrees with mine. I found that frequency of nest material trip reached the peak at 50-60 days old young
(Figs. 5.8a & b). From my observations I can deduct that the age of the young (when they had started “jumping”, see Saikia and Bhattacharjee, 1996a) could be 50 to 60 days. However, due to lack of enough data in the pre-egg-laying and pre-hatching periods the first peak was not found in my observation (Fig. 5.8a). Of course, more hours of observation was done in the second breeding season before hatching of chick, where the first peak could be seen (Fig. 5.8b). In American Wood Stork also a second peak of the frequency of nest material trip was found at the age of 30-days old chick (see Coulter, 1989b).

It is obvious that during the initial stage of nest building, more and more nest material is needed; hence the first peak. During the incubation period there was a comparative stability of collecting nest material. When the chick(s) hatched, the nest platform also became a roosting site for the parent and chick(s) together and feeding place for the chick(s). As they grow more and more space is required and so more nest sticks are brought for lining the nest. Once the juveniles start moving around (post-flying juvenile stage) they do not spend much time on the nest and therefore need of nest material decreases. Parents also indirectly encourag them to fly by bringing fewer nest material and food (see below). I also found that the number of nest material trips and the quantity of the nest material brought to the nest, also depends on the number of young ones raised (Fig. 5.9a, 2 young and fig. 5.9b, 1 young).

Rodgers, JR. et al. (1988) elaborately discuss different hypotheses put forward by some authors regarding the use and function of green nest material by storks and have
come to conclusion that primary function of nest greenary is to enhance insulation of
nest. They found that their conclusion is applicable more to twiggy, porous nests. They
also state that greenary may function in maintaining the stork pair bond. Besides the
fresh green twigs, GAS also collected dry nest sticks from abandoned or vacated nests.
Mertens (1977) concluded that dry material provide better insulation than fresh
vegetation. The Painted Stork moistened dry sticks in water before use (Desai et al.,
1977) which contradicts Mertens’ view. However, Hume and Oates (1890) hypothesised
a cause for moistening nest (see below). I think this behaviour is probably related to
the same reason for which water is brought to the stork’s nest (see below).

Re-ingesting of food by the parent storks was seen in the early chick stage because at
this stage they could not consume all food including big size fish and those were re-
ingested by the parent only to regurgitate later on. When the young grew up they could
easily swallow big size food and hence parents no longer re-ingested. This activity was
associated with the foraging trips when food were brought at noon and hence more re-
ingestion was seen during noon and afternoon (Figs. 5.5a & b and 5.6a & b).

My studies reveal that the male GAS brought more food than the female. In American
Wood Stork, (Coulter, 1989b) found that both sexes made similar number of foraging
trips.

In the early chick stage they were fed mainly fish and amphibians which appeared to
be surplus up to three-week old chick stage. The whole-vertebrate food is required due
to their high calcium need during rapid growth (Kahl, 1966b). Foraging trip frequency in GAS increased with the age of the young up to 3 months, then it fell down. Similar observation was done in American Wood Stork, where frequency of foraging trip increased up to 40-51 days old young (Coulter, 1989b). It should be noted here that the first flight in American Wood Stork is seen at 60 days age compared to 100 days age in GAS.

The quantity and size of food brought by parent storks depend greatly on the age of nestlings (Kahl, 1964). Early in their life, the young storks consume a much larger quantity of food in proportion to their size than they did later (Kahl, 1962). Of the total food consumed in the nest, 50% is eaten during the middle third of the nestling period. Similar pattern was seen in GAS too. When both parents stayed away from nest at the age of six weeks, they could bring more food for the young. Though fish was the major food item in Marabou Stork in Uganda (Pomeroy, 1977a). Kahl (1966a) reported Marabou bringing some food from rubbish dump and abattoir. This type of substitute food also was brought by parent GAS after young were approximately seven-week old (Bhattacharjee and Saikia, 1996). I also saw similar observation, but I disagree with their observation that chicks were offered smaller fish till the age of 12 days, and then gradually larger fish were offered. I found that the parents were opportunistic as far as the food size was concerned i.e., the size of the fish was not related with the size of the young ones. If they were able to catch a large fish, it was softened by repeatedly regurgitating and grinding between mandibles (as already described in section 5.3.32). I suppose, the GAS were not selective in prey choice during the
breeding season. This food supplement seems to be an adaptation to overcome the food scarcity and is not related only with the age of juveniles.

The Greater Adjutants are opportunistic feeder. During the non-breeding summer season, when they are supposed to scavenge on garbage dumps, during early monsoon, if some low lying area were inundated by rainfall, they were seen to forage there. In the beginning of winter when water-bodies started receding, they had easy prey in drying up pools, but in late February onwards when all shallow water-bodies dry up, which coincided with the juvenile stage, they had no option but to scavenge and prey on other animals. Bhattacharjee and Saikia (1996) also hold the same view. At this time, they even brought domestic ducks to feed the young. Marabous are also found to hunt young heron (Pomeroy, 1977a) and pelican nestling (Din and Eltringham, 1974). Moreover, juvenile GAS are able to feed on such type of food (ducks). Food robbing by parent storks from other’s nest also was seen.

Water is brought to the stork’s nest during egg as well as nestling periods (see Kahl, 1970). Hume and Oates (1890) hypothesised that such moisture aids in fermentation, which in turn add warmth for incubation. On the other hand, Coulter (1989b) reported that water trips were more common on very hot days, though he did not see a monthly increase in the frequency or frequency increasing with age of the chick. I only saw three water trips by the male GAS in the first breeding season and those were not at noon, rather one trip was during cold foggy weather.
The 'miscellaneous trips' in which GAS did not bring anything, were found to vary in the two breeding seasons (Figs. 5.7a & b). Coulter (1989b) found that the frequency of these trips declined as the breeding season progressed. But I did not find any definite trend of the frequency of these trips. Most of the time, these trips were made for chasing storks. And since aggressive behaviour varied individually, the trips also varied accordingly.

5.4.3 INCUBATION AND FLEDGING PERIOD

Though daily monitoring in the colony twice a day was sufficient to find out reproductive phenology of GAS i.e. date of nesting, egg-laying and incubation, hatching and fledging, and also to observe nest abandonment, re-nesting, young mortality, there was also some drawbacks.

Where counting of eggs was not always possible, I followed Coulter's method (1989b) to know the initiation of incubation and clutch size. To guess the hatching date of first chick and thus estimating the incubation period I followed on indirect evidences. My method resembles with that of Pomeroy (1978a). He estimated the age of the young "fairly accurately" from their appearance to get the date of hatching, but I do not agree that one can accurately estimate the age of a chick just by looking at the plumage and appearance. It would definitely vary from individual to individual (as I observed on different nests) and it would not be wise to say that a particular appearance occurs at a particular age only. For example, Pomeroy (1978a) says that a 93 days old chick of Marabou Storks would have black back with white feathers. In GAS, I found that chick
growth was quite varied, i.e., a particular stage could not be always assigned to a particular age. Some chicks grew very fast while other chicks of the same age lagged behind.

Though I have estimated the average incubation period of GAS as approximately 40 days, and there was no significant difference between two year's data, yet I admit that this is probably a maximum estimate. The more accurate incubation period is around 35 days (34.6 ± 2.70 s. d. days, n = 5). In some nests, prolonged incubation period exceeding 35 days was noticed. In one case even when the first chick had grown to 30 days, unhatched egg was still being incubated. Finally, it was dropped from the nest. Prolonged incubation has been reported in a number of bird species (Drent, 1975; Skutch, 1962; Afik and Ward, 1989). Drent (1975) suggested that prolonged incubation was a functional response caused by the inherent variability in incubation period. Marks (1983) is of the view that prolonged incubation behaviour is related to the time interval in which entire clutch would normally hatch which seems not fit in case of GAS whose clutch size is small and eggs hatch at a short time interval. Prolong incubation is also reported from Painted Stork (Desai et al., 1977). Pomeroy (1978a) reports that one pair of Marabous incubated for 150 days, and eventually one young fledged from that nest. He regarded this case as re-laying of eggs in the same nest. He found 8% re-laying cases in Marabau stork. I also found 7.5% cases of probable re-laying in GAS. In three nests I also found prolonged incubation period consisting of 93, 97 and 107 days which I suspects are cases of re-laying (see Appendices 5.1 and 5.2). This proportion (7.5%) is very close to the proportion of 8% found in Marabou Stork.
According to Lack (1968), the incubation period in ciconiidae varies between 30-33 days. Incubation period in GAS earlier reported is 30 days (Saikia and Bhattacharjee, 1996b). It seems that my estimate of incubation period in GAS is longer than other storks: 32 days in American Wood Stork (Heinzman and Heinzman, 1965), 32 days in White Stork (Schuz, 1972), 29-32 days in Maguari Stork (Thomas, 1984; 1986), 32 days in Painted Stork (Desai et al., 1977), 30-31 days in Whitenecked Stork (Scott, 1975), 28-30 days in Abdim's Stork Ciconia abdimii (Farnell and Shannon, 1987) and 29-31 days in Marabou stork (Brown et al., 1982; Kahl, 1966b; Pomeroy, 1978a).

The average fledging period of GAS from hatching till fledging was about 140 days which varied considerably from 96 to 197 days. In Painted Stork also nesting period was found to range from 100 to 140 days varying considerably with individuals (Desai et al., 1977). The fledging period (hatching to leaving the nest) in Marabou Stork was found to be 132-135 days (Kahl, 1966b; Pomeroy, 1978a). The fledging period in GAS colony varied in different pairs. There was a gap of 67-74 days between first and last fledging in the colony. I also found that early hatched young did not necessarily fledged earlier because in few cases the late hatched chicks fledged earlier. Even the siblings of the same nest fledged asynchronously; and sometimes the second or third chicks fledged earlier than the first clutch.

5.4.4 REPRODUCTIVE SUCCESS

It is found that though more or less equal number of nesting attempts were made and equal number of nests were built in both seasons, in the first season the GAS used
more trees. Though crowding was started in September in both the study years, in 1995-96 GAS built nest in September while in 1996-97, nests were built one month later, accordingly the fledging time was also delayed. The over all breeding period in the entire colony was quite long (eight to nine months: September through May) than that of Marabou Storks (six to eight months; Pomeroy, 1986).

More nests were abandoned in the second breeding season than the first. A total of seven re-nestings were recorded in the colony. However it was not known whether the same pair or other storks re-built the nests. Nest abandonment and re-nesting are also reported in American wood Stork (Coulter, 1989b) and Marabou Stork (Pomeroy, 1978a).

I found that the clutch size in the GAS varies from 1 to 4 eggs, although a four-egg clutch is very rare. However, four-egg clutch was reported by Hume and Oates (1890). Two-eggs clutch was found to be the most common in both the seasons. Saikia and Bhattacharjee (1996a) and Bhattacharjee and Saikia (1996) report that the clutch size of GAS usually varies between two to three and three being the commonest. They found the mean clutch size is 2.61, while I found the average clutch size of both seasons was $1.9 \pm 0.74$ (n = 50). The average clutch size of other stork species are listed below: $2.85 \pm 0.74$ in American Wood Stork (Coulter and Bryan, JR., 1995); two to four in White Stork, four being more common (Lack, 1973); one to four in Marabou Stork, three being common (Brown et al., 1982); 3.2 in Maguari Stork (Thomas, 1984); 2.49 in Painted Stork, two to three being more common (Desai et al., 1977).
Lack (1954) postulated a hypothesis that the clutch size of each species of bird has been adapted by natural selection to correspond with the largest number of young for which the parents can, on the average, provide enough food. Perrins and Birkhead (1983) state that commonest clutch size is often smaller than the most productive one. Laying slightly conservative-size clutch, adult survival may be enhanced. In my study also it was seen that the most productive clutch was three. In the first breeding season there were five three-egg clutch, four of them were of the early breeder and one was of the late breeder. All four clutches of the early breeding period were successful than that of the late breeding period (see below). Though GAS could produce three-egg clutch size successfully, yet the common clutch size was two-egg which agrees with the views of Perrins and Birkhead (1983). In American Wood Stork also four-egg clutches fledged more storks, though three-egg clutches were most frequent (Rodgers, JR. and Schwikert, 1997).

Pomeroy (1978a) is of the view that a convenient definition for the breeding success of a colony is the average number of young fledged for every nest in which eggs were laid. But on the contrary, Coulter (1989b) states that in order to obtain a reproductive success per nest in a colony, nests that failed must also be considered. I have calculated fledging success of the whole colony as well as of the successful nests which produced at least one hatchlings. Though both ways of calculations helped to compare results of different authors, I feel the view of Coulter (1989b) is logical. As I could not see the eggs in all the nests, hatching success of the whole colony could not be estimated. Hence an overall reproductive success was not possible to find out.
However, fledging success is enough to reflect seasonal addition of GAS young to the population.

Saikia and Bhattacharjee (1996a) say that the hatching success of GAS was 90%, fledging success out of hatched young was 68.08% and over all reproductive success was 61.30%. Combining the two year’s data, I found 77.42% (72 young fledged out of 92 hatched) fledging success in GAS. Thomas (1984) studied reproductive success of Maguari Stork from 1973-1981 and has come out with the result that on an average fledging success of Maguari Stork was 85% and the reproductive success was 61.5%. Coulter and Bryan, JR. (1995) found average fledging success of American Wood Stork was $1.37 \pm 1.32$ (52%) of six consecutive breeding seasons. Rodgers, JR. and Schwikert (1997) reported that $1.29 \pm 1.16$ fledglings of American Wood Stork per nest for all the colonies. Based on a six years study of Painted Stork, (Desai et al., 1977) found fledging rate of 1.1 young per pair. Kahl (1966b) reported that over all breeding success of Marabou stork was 0.85 per nest. My result shows that for the entire colony in two successive breeding seasons, 0.87 GAS fledged per nest. It seems that except these two congeneric Leptoptilos, other species of storks have better fledging success. But every author’s data shows that reproductive success varies in each year and in different colonies. In GAS also I found fledging success of first year’s breeding season was higher than that of second year. Only two season’s data may not depict a complete picture of GAS breeding success, yet two year’s fledging success can be compared on the basis of following factors.
The meteorological information shows that in the beginning of the second breeding season there was less rainfall and it was more colder and humid. As it has been already discussed in section 5.4.1 that food availability is related to rainfall and food shortage early in the season may delay breeding. Though nesting attempts were made in September in both the breeding seasons, it is seen that first nest of the second breeding season was built one month later than the first breeding season, and consequently the last juvenile fledged one month later in the second breeding season.

Though surrounding habitats of GAS were not surveyed, it can be guessed that probably there was shortage of food in the second breeding season due to the less rainfall in early part of the season. Food availability proportionately varies with the amount of rainfall (Desai et al., 1977). They have shown, comparing six consecutive year’s data, that low rainfall resulted in poor reproductive performance in Painted Stork. The importance of food is one factor affecting reproductive success in wading birds (Kahl, 1964; Clark, 1979). Coulter and Bryan, JR. (1995) have proved that there was a significant relationship between average yearly prey density at foraging sites of American Wood Storks and the average number of young fledged from successful nests. Timing of breeding can also be modified by the weather. Humidity of the air is important in controlling water loss through the skin and lung of animals (Krebs, 1985). Cold weather early in the season may stress the storks and lead to nest desertion (Coulter and Bryan, JR., 1995). They also observed that winter and early spring cold may limit storks from breeding earlier than they do. These reasons might explain why there were more nest desertions and late nesting in the second breeding season in my
study area. Another important observation was that in the first breeding season (1995-96) maximum nests were built in the early breeding period; whereas in the second breeding season (1996-97), more nests were built in the late breeding period. Moreover, in warmer weather, birds need less food to maintain themselves (Perrins and Birkhead, 1983). Coulter and Bryan, Jr. (1995) also observed that during cold weather, storks left to forage for longer periods of time. Same behaviour was observed by me in the second breeding season when exchange of partner took place after longer duration, and sometimes storks left unguarded chick for foraging.

Within a breeding season the younger birds often breed later than do older adults (O'Conner, 1984; Perrins and Birkhead, 1983; Ford, 1989). Improved reproductive success is often associated with age and experience (Greenwood, 1980; Hornberger, 1967). In Marabou Storks, Pomeroy (1978a) found that there was a strong suggestion that success was greater in early breeders. In many species late breeding attempts are relatively unsuccessful and produce few surviving young (Perrins and Birkhead, 1983). My findings in this regard also support their observations. The mortality was higher in the late breeding period. All three-egg clutch in the early breeding period in the first breeding season were successful. In addition to this, mortality rate was higher 1996-97 which indicates that the first breeding season (1995-96) was a “good” year and the second year was a “bad” year.

Saikia and Bhattacharjee (1996a) state that fledging success of GAS is constrained by scarcity of food, weather extremes, mortality of parents, accidental drop of nestling and nest destruction. In American Wood Storks, Coulter and Bryan, Jr. (1995) identified
five sources of mortality: storm damage, intra-specific aggressions, predation, cold weather and unknown causes.

I found that most of the GAS mortality occurred at chick stage (excluding egg stage mortality). Five chicks and one juvenile were found dead in the nest out of which only two belonged to four-egg clutch in the early breeding part. The actual cause can not be ascertained but apparently they died due to food shortage in the late breeding period which has already been discussed. In the second breeding season a late breeder was seen to bring dead animal food to the chick which suggests probable live-prey scarcity. Because in the first breeding season the GAS did not bring this kind of food at this chick stage. The two deaths died in the four-egg clutch could be explained by Lack's brood reduction hypothesis. Though in the early part of the first year food seemed to be available, probably the GAS could not raise more than two young ones. Pomeroy (1978a) observed that the third chick in a clutch of a colony of Marabou Stork rarely survived.

I found some dead chicks below the tree which were suspected to have fallen down accidentally. One juvenile with a deformed wing was unable to stand on the nest, so it fell to death. Ten percent Marabou Stork die simply falling from the nest (Pomeroy, 1977a). Sometimes weak juvenile also fell down from nest during thunder storm. Similar cases were reported in Marabou Stork also (Pomeroy, 1977a). While robbing nest material in the absence of parents, two chicks were killed by other invading storks. The invaders dropped the chicks down. Kahl (1966b) reported that Marabous
occasionally destroy their own eggs. I did not see this behaviour in GAS. I also did not find any sign of predation of young ones.

Looking into all the above aspects and comparing its biology with other storks it appears that the Greater Adjutant Stork resembles in most of its behaviour and biology with congeneric Marabou Stork. Seasonal fluctuation of breeding success is seen in every stork species and in many cases it is related to environmental factors. The long breeding season of this colonial bird has an important phase in its life cycle during which the most crucial life requisite seems to be food. Owing to its long breeding period, the GAS is susceptible to numerous environmental factors.
Appendix 5.1
Breeding records of Greater Adjutant Stork in North Haibargaon nesting colony during 1995-96 breeding season

<table>
<thead>
<tr>
<th>Nest Tree</th>
<th>Nest</th>
<th>Nesting Date</th>
<th>Incubation Date</th>
<th>Hatching Date</th>
<th>Incub. Perio (Days)</th>
<th>No. Hatch</th>
<th>No. Died</th>
<th>No. Fledged</th>
<th>Fledging Date</th>
<th>Fledg. Perio (Days)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
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<td>A</td>
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<td>?</td>
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<td>?</td>
<td>1</td>
<td>0</td>
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<td>8 Apr 96</td>
<td>181*</td>
<td>Abandoned between 31 Jan. and 13 Feb. 96</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7 Sep 95</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td></td>
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<td>194*</td>
<td>First flight of juvenile seen on 26 Mar. 96</td>
</tr>
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<td>?</td>
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<td>First flight of juvenile seen on 27 Mar. 96</td>
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<td>196*</td>
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</tr>
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<td>27 Sep 95</td>
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<td>18 Apr 95</td>
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<td>17 Nov 95</td>
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<td>0</td>
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<td>1 May 96</td>
<td>166</td>
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<tr>
<td></td>
<td>F</td>
<td>6 Nov 95</td>
<td>12 Nov 95</td>
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<td></td>
<td>5 Dec 95</td>
<td>6 Dec 95</td>
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<td>?</td>
<td>?</td>
<td>?</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>11 Apr 95</td>
<td>211*</td>
<td>First flight of juvenile seen on 18 Mar. 96</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>10 Sep 95</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>11 Apr 95</td>
<td>214*</td>
<td>First flight of juvenile seen on 28 Mar. 96</td>
</tr>
<tr>
<td></td>
<td>C</td>
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<td>17 Nov 95</td>
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<td>26 Mar 96</td>
<td>34</td>
<td>2</td>
<td>1</td>
<td>26 Mar 96</td>
<td>96</td>
<td>On 14 Mar. 96 one juvenile found dead in the nest. First flight of juvenile seen on 18 Mar. 96.</td>
</tr>
<tr>
<td>Dm2</td>
<td>A</td>
<td>4 Oct 95</td>
<td>10 Oct 95</td>
<td>19 Nov 95</td>
<td>40</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>21 Apr 95</td>
<td>154</td>
<td>First flight of juvenile seen on 14 Mar. 96.</td>
</tr>
<tr>
<td></td>
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<td>13 Oct 95</td>
<td>21 Nov 95</td>
<td>39</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>5 Apr 96</td>
<td>136</td>
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</tr>
<tr>
<td></td>
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<td>28 Nov 95</td>
<td>3 Dec 95</td>
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<tr>
<td></td>
<td>G</td>
<td>15 Oct 95</td>
<td>19 Oct 95</td>
<td>23 Nov 95</td>
<td>35</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>3 May 96</td>
<td>162</td>
<td>First flight of juvenile seen on 26 Mar. 96.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>15 Oct 95</td>
<td>20 Oct 95</td>
<td>23 Nov 95</td>
<td>34</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>29 Apr 95</td>
<td>158</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>4 Oct 95</td>
<td>12 Oct 95</td>
<td>21 Nov 95</td>
<td>40</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>29 Apr 95</td>
<td>160</td>
<td>First flight of juvenile seen on 14 Mar. 96. One juvenile had fledged on 20 Mar. 96.</td>
</tr>
<tr>
<td></td>
<td>Jk1</td>
<td>A</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>?</td>
<td>?</td>
<td>The nest was discovered on 24 Jan. 96 with two chicks. Till 10 June 96 did not fledge.</td>
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<td></td>
<td></td>
<td></td>
<td>Abandoned on 24 Nov. 95.</td>
</tr>
<tr>
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<td>K1</td>
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<td>23 Nov 95</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Renesting. Hatching between 31 Jan-13 Feb. 96</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>14 Dec 95</td>
<td>19 Dec 95</td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td></td>
<td>One chick found dead below the tree on 20 Mar 9.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>10 Oct 95</td>
<td>15 Oct 95</td>
<td>18 Nov 95</td>
<td>34</td>
<td>2</td>
<td>0</td>
<td>11 Mar 9</td>
<td>145</td>
<td>Another chick died in the nest on 29 May 96.</td>
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<td></td>
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<td>27 Sep 95</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>First flight of juvenile seen on 27 Mar. 96.</td>
</tr>
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<td></td>
<td></td>
<td>B</td>
<td>10 Oct 95</td>
<td>15 Oct 95</td>
<td>18 Nov 95</td>
<td>34</td>
<td>2</td>
<td>0</td>
<td>11 Apr 9</td>
<td>145</td>
<td>Abandoned on 12 Jan. 96.</td>
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<td></td>
<td></td>
<td></td>
<td>First flight of juvenile seen on 27 Mar. 96.</td>
</tr>
<tr>
<td>Mj1</td>
<td>A</td>
<td>18 Sep. 95</td>
<td>23 Sep. 95</td>
<td>30 Oct. 95</td>
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<tr>
<td>B</td>
<td>15 Sep. 9</td>
<td>20 Sep. 95</td>
<td>4 Nov. 95</td>
<td>28 Feb. 96</td>
<td>116</td>
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</tr>
<tr>
<td>Mj2</td>
<td>A</td>
<td>?</td>
<td>7 Nov. 95</td>
<td>?</td>
<td>28 Apr. 9</td>
<td>155</td>
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</tr>
<tr>
<td>B</td>
<td>13 Sep. 95</td>
<td>21 Sep. 95</td>
<td>15 Nov. 95</td>
<td>14 Apr. 9</td>
<td>151</td>
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<tr>
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<td>12 Oct. 95</td>
<td>12 Nov. 95</td>
<td>22 Apr. 9</td>
<td>162</td>
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<td>22 Apr. 9</td>
<td>159</td>
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</tr>
<tr>
<td>B</td>
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<td>9 Oct. 95</td>
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<tr>
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<td>18 Oct. 95</td>
<td>19 Nov. 95</td>
<td>21 Apr. 9</td>
<td>154</td>
<td></td>
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</tr>
<tr>
<td>B</td>
<td>23 Nov. 95</td>
<td>3 Dec. 95</td>
<td>14 Jan. 96</td>
<td>28 Mar. 9</td>
<td>153</td>
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<td>A</td>
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</tr>
<tr>
<td>Mj6</td>
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<td>8 Dec. 95</td>
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<td>10 Dec. 95</td>
<td>18 Jan. 9</td>
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</tr>
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</table>

** Other juvenile fell down on 26 Apr. 96. It was rearmed and later released.

Total: 61

Tree code:
- D (Devil tree): *Alstonia scholaris*
- G (Gahaera): *Premna benghalensis*
- K (Kadam): *Mitragyna parvifolia*
- Mj (Moj): *Albizia lucida*
- Dw (Dowa): *Artocarpus lakoocha*
- Jk (Jackfruit): *Artocarpus heterophyllus*
- T (Thekera): *Garcinia cowa*

* Fledging period counted since nest building date.

Abandoned between 31 Jan.-13 Feb. 96.
Two chicks died in the nest on 8 Nov. and 12 Nov. 95. Greatest clutch size seen in the colony. Clutch size was three. One egg did not hatch. It was dropped on 6 Dec. 95.

First flight of juvenile seen on 26 Mar. 96.

First flight of juvenile seen on 20 Mar. 96.
Abandoned on 19 Oct. 95.
First flight of juvenile seen on 26 Mar. 96.
One chick died in the nest on 14 Mar. 96. Other first flight of juvenile seen on 26 Mar. 96.

Abandoned between 31 Jan.-13 Feb. 96.
Abandoned on 25 Feb. 96.

Abandoned on 30 Oct. 95.
Abandoned on 21 Nov. 95.
Abandoned on 8 Nov. 95.
One chick fell down and died on 5 Apr. 96.

Abandoned on 13 Nov. 95.
Renesting. Abandoned again on 27 Dec. 95.

Abandoned on 12 Jan. 96.

Hatching date: first chick hatched
Fledging date: first juvenile fledged
## Appendix 5.2

**Breeding records of Greater Adjutant Stork in North Haibargaon nesting colony during 1996-97 breeding season**

<table>
<thead>
<tr>
<th>Nest Tree</th>
<th>Nest</th>
<th>Nesting Date</th>
<th>Incubation Date</th>
<th>Hatching Date</th>
<th>Incub. Period (Days)</th>
<th>No. Hatch.</th>
<th>No. Died</th>
<th>No. Fledged</th>
<th>Fledging Date</th>
<th>Fledg. Period (Days)</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>D1</td>
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<td>22 Sep. 96</td>
<td>6 Oct. 96</td>
<td>11 Jan. 97</td>
<td>34</td>
<td>2</td>
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<td></td>
</tr>
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<td>D</td>
<td>3 Dec. 96</td>
<td>8 Dec. 96</td>
<td>11 Jan. 97</td>
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</tr>
<tr>
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<td>19 Sep. 96</td>
<td>22 Sep. 96</td>
<td>8 Nov. 96</td>
<td>47</td>
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<td>2</td>
<td>24 May 97</td>
<td>197</td>
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Abandoned on 25 Sep. 96.
Renesting, abandoned again on 7 Nov. 96.
Abandoned on 4 Nov. 96.
Abandoned on 10 Nov. 96.
Chicks dropped by another GAS on 1 Feb. 97.
Abandoned on 20 Jan. 97.
Dropped on 22 Dec. 96 and 23 Mar. 97.
Both fledged together.
Dropped on 6 Jan. 97; reared and released.
The last juvenile fledged from the colony.
Abandoned on 14 Dec. 96.
Renesting, abandoned again on 6 Mar. 97.
The first juvenile fledged from the colony. The second juvenile fledged on 8 Apr. 97.
Abandoned on 4 Nov. 96.
Found dead below the tree on 10 Nov. 96.
Abandoned on 14 Oct. 96.
Abandoned on 21 Oct. 96.
Abandoned on 10 Nov. 96.
The second juvenile fledged on 26 May 97.
Abandoned on 14 Oct. 96.
First flight of the juvenile was seen on 18 Mar. 97.
Abandoned on 26 Nov. 96.
Abandoned on 31 Oct. 96.
Attempt failed to build the nest.
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* Not considered in the incubation period analysis

Hatching date: first chick hatched
Fledging date: first juvenile fledged

Tree code:
D (Devil tree): *Alstonia scholaris*
Jk (Jackfruit): *Artocarpus heterophyllus*
Th (Thekera): *Garcinia cowa*

Dn (Dimuru): *Ficus glomerata*
K (Kadami): *Mitragyna parvifolia*
Mj (Moj): *Albizia lucida*
Chapter 6

BEHAVIOUR DURING NON-BREEDING SEASON
CHAPTER 6

BEHAVIOUR DURING NON-BREEDING SEASON

6.1. INTRODUCTION

After breeding, the Greater Adjutant Storks along with newly fledged juveniles leave the breeding colony and move locally to some regular foraging grounds. These foraging grounds include garbage dumps, places near meat and fish markets and slaughter houses in major towns. These grounds are used by the GAS year after year during non-breeding season when they concentrate more on scavenging than going for live prey. However, in the early monsoon, when crop fields and low lying areas are inundated, they scatter and disperse from the regular foraging grounds in search of live prey.

Compared to the long breeding season, the non-breeding season is short and lasts only three to four summer months (May through August). Although of short duration, the non-breeding season is important because during this period the adult GAS regain their lost energy in the previous breeding and prepare for the next breeding. The newly fledged juveniles start foraging and adapt themselves to the new habitat condition.

Due to their colonial and gregarious habits, the GAS gather in flock during the non-breeding period. The term flock is applied to any aggregation of homogenous individuals, regardless of size or density (Emlen, JR., 1952). He further proposed that the form and density characteristics of bird flocks are determined by the interplay of positive and negative forces associated with gregariousness on the one hand and intolerance and independence on the other. It was my interest to know how these
forces work in the flocking behaviour of GAS. As during the brief post-breeding period, they are found to aggregate in particular habitats, my main objective was to know how they use the human related artificial food resources. Some workers (Tacha, 1988; Rahmani, 1991) have studied different behaviour pattern of male and female birds in a flock. As it was difficult to distinguish sex of GAS other than on nest, I studied how behaviour of juveniles and sub-adults was different with that of adults.

I selected two study sites to study the diurnal flocking behaviour of GAS. The detail description of these two sites (Guwahati and Nagaon) has been given in section 2.7.2. Both the sites were regular foraging ground of GAS during the non-breeding season; however, they were different in some aspects. The study site in Guwahati was a huge municipal garbage dumping ground where throughout the day, garbage and city refuse were being brought, thus providing continuous food supply to the scavengers. The other study site at Nagaon was a barren field along the bank of a rivulet where inedible animal parts from slaughter houses were brought at night and diurnal scavengers used to feed them only in the morning. Here after I shall refer study site at Guwahati and Nagaon as Urban Garbage Dump and Rural Garbage Dump respectively. I wanted to know whether difference in the habitat type had an affect on the flocking behaviour of the GAS.

6.2 METHODS

I studied behaviour and activities of GAS at Guwahati and at Nagaon in June and July 1996 respectively. As GAS stay in flock, it was difficult to follow a focal stork throughout
I observed GAS from morning through evening (0600 to 1800 hrs.) continuously without any break. However, 12 hrs. of observation was not always possible due to unavailability of the minimum flock size. Sometimes I had to start after 0600 hrs. and sometimes had to finish before 1800 hrs. as ten or more than ten storks were not present. Therefore, total observation duration were 117.5 hrs. (706 observations) and 106 hrs. (647 observations) at Urban Garbage dump (Guwahati) and Rural Garbage
Dump (Nagaon) respectively. Ten full day observations were done both at Guwahati (16 June to 28 June 1996) and at Nagaon (19 July to 28 July 1996). The activities were grouped into ten categories: (1) Resting (including standing, loafing, lying and with no motion other than alertness) (2) preening (3) Walking and running (movements of the storks without flying and with no intention of foraging) (4) Foraging (including food searching, catching and swallowing) (5) Wing stretching (may be one or both the wings for sunning) (6) Fighting (including frontal clash with the bill and chasing to snatch food) (7) Drinking (8) Flying (including leaping, flying for short distance; soaring in the sky was excluded as this was considered out of the studied flock) (9) Alertness (when the GAS showed alert posture with erect and slightly arched neck) (10) Others (defecation, landing, yawning etc.)

Apart from these, extra information were noted in the field note book which could not be accommodated in the data sheet.

6.3 HYPOTHESES

(1) There is no association between different activities and weather condition.

(2) There is no significant difference in activities of adult and juvenile storks.

(3) There is no significant difference of stork activities at urban and rural garbage dumps.
6.4 ANALYSES

As I scanned and counted the number of storks doing a particular activity during each sample period, time spent per activity was not evaluated, instead percentage of storks in the flock doing each activity was calculated. All the analyses were done by STATA 5.0 program (Stata corp., 1993). Percentage of storks doing different activities for the total observation period as well as at three duration of day (morning 0600 to 1000 hrs., noon 1000 to 1400 hrs. and afternoon 1400 to 1800 hrs.) was calculated both at Guwahati and Nagaon separately. For doing statistical tests, percentages of storks were transformed into arc sine values. Unpaired t-test was performed to see the significant differences of mean percentages of adults and juveniles in different activities at both the study sites. The Pearson Product Moment correlation was done to see the associationship of percent number of storks in different activities with weather and cloud cover at both the places. Another unpaired t-test was done to testify the differences of mean of stork percentages (adult and juvenile separately) doing different activities at Nagaon and Guwahati.

For graphical representation, I combined some similar activities under one head. Foraging and drinking were put together as 'basic intake' activity, wing stretching and preening were combined together as 'maintenance', and walking plus flying together were categorised as 'locomotion' activity. Although alertness could have been placed with 'resting', due to different posture and function, it was considered an independent behaviour.
6.5.1 Percentage of storks in different activities

At Guwahati garbage dumping site, a maximum of 120 adults and 70 juveniles were observed. However, the daily average was 56 adults and 37 juveniles. At the Nagaon garbage dumping site, I counted a maximum of 81 adults and 35 juveniles but the daily average was 40 and 12. The general pattern of stork percentage involved in different activities at Urban Garbage Dump (Guwahati) and Rural Garbage Dump (Nagaon) is depicted in Figs. 6.1a and 6.2b respectively. It is seen that throughout the day, the percentage of adult and juvenile stork in all activities was almost similar in both the places. More number of GAS were found resting compared to other activities. In comparison to adults, more juveniles spent time in resting. Next to resting, maintenance activity was most frequently observed; percentage of adults indulging in this activity was more than juveniles. At Urban Garbage Dump, more number of GAS were seen fighting, alert, moving, foraging and drinking than Rural Garbage Dump, while maintenance activities were more seen at the latter site than at the former.

The trend of stork percentage in different activities remained almost similar in morning, noon and afternoon (Figs. 6.2a and 6.2b). At Urban Garbage Dump, a gradual increase of storks seen resting was found, whereas at Rural Garbage Dump the number of adults resting remained almost same, but a larger number of juveniles found to take rest at noon. At both the garbage dumps, maintenance activities were seen in a lesser number of storks at noon time. The number of storks involved in foraging, walking or running and fighting increased at noon time at both the places.

There was a very weak correlation between the number of storks doing different activities and the weather and cloud cover. Except a little correlation between the
Fig. 6.1a Activities of adult and juvenile storks at Urban Garbage Dump (Guwahati, June 1996)

Fig. 6.1b Activities of adult and juvenile storks at Rural Garbage Dump (Nagaon, July 1996)
Fig. 6.2a. Stork activities at different time of the day
Urban garbage dump (June 1996)

Fig. 6.2b. Stork activities at different time of the day
Rural garbage dump (July 1996)
number of storks in resting and the weather and cloud cover, all other associationships were negligible.

At Urban Garbage Dump the percentage number of adult storks differed significantly with that of juveniles in resting, preening, foraging, walking or running and alertness; while at Rural Garbage Dump significant differences were found between adults and juveniles in resting, fighting and drinking (Table 6.1). The newly fledged juveniles appeared to be unfamiliar to the habitat type and they were found less to forage and more to rest than the adults did.

Table 6.1 Comparison of percentage mean number of adult and juvenile Greater Adjutant Storks in different activities.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Urban Garbage Dump (df = 1408) t value</th>
<th>Rural Garbage Dump (df = 1271) t value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resting</td>
<td>-3.4831***</td>
<td>-4.9999***</td>
</tr>
<tr>
<td>Preening</td>
<td>3.6798***</td>
<td>-1.1945</td>
</tr>
<tr>
<td>Wing stretching</td>
<td>1.9395</td>
<td>-0.4653</td>
</tr>
<tr>
<td>Foraging</td>
<td>4.0916***</td>
<td>-1.7056</td>
</tr>
<tr>
<td>Walking</td>
<td>-4.2601***</td>
<td>-1.7433</td>
</tr>
<tr>
<td>Fighting</td>
<td>0.9874</td>
<td>-3.2350**</td>
</tr>
<tr>
<td>Drinking</td>
<td>1.1462</td>
<td>-2.6848**</td>
</tr>
<tr>
<td>Flying</td>
<td>-1.8073</td>
<td>0.1714</td>
</tr>
<tr>
<td>Alert</td>
<td>2.6306**</td>
<td>-1.5625</td>
</tr>
<tr>
<td>Others</td>
<td>-0.6264</td>
<td>-1.2444</td>
</tr>
</tbody>
</table>

Significant at *p<0.05, **p<0.01 and ***p<0.001

The percentage number of adult storks at Urban Garbage Dump significantly differed with that of Rural Garbage Dump in every activities except drinking, flying and other activities; while percentage number of juveniles of these places was significantly different in resting, preening, wing stretching, drinking and other activities (Table 6.2).
Table 6.2 Comparison of percentage mean number of Greater Adjutant Storks in different activities at two different habitats: Urban Garbage Dump and Rural Garbage Dump.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Adults (df = 1342)</th>
<th>Juveniles (df = 1337)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t value</td>
<td>t value</td>
</tr>
<tr>
<td>Resting</td>
<td>-5.7055***</td>
<td>-6.6530***</td>
</tr>
<tr>
<td>Preening</td>
<td>-9.2310***</td>
<td>-8.5585***</td>
</tr>
<tr>
<td>Wing stretching</td>
<td>-2.2350*</td>
<td>-3.4536***</td>
</tr>
<tr>
<td>Foraging</td>
<td>16.0656***</td>
<td>1.8371</td>
</tr>
<tr>
<td>Walking</td>
<td>3.1127**</td>
<td>0.5940</td>
</tr>
<tr>
<td>Fighting</td>
<td>6.2288***</td>
<td>-0.1700</td>
</tr>
<tr>
<td>Drinking</td>
<td>-0.6084</td>
<td>-4.2501***</td>
</tr>
<tr>
<td>Flying</td>
<td>-0.9012</td>
<td>0.4424</td>
</tr>
<tr>
<td>Alert</td>
<td>6.4539***</td>
<td>-0.5493</td>
</tr>
<tr>
<td>Others</td>
<td>-1.8745</td>
<td>-2.2308*</td>
</tr>
</tbody>
</table>

Significant at *p<0.05, **p<0.01 and ***p<0.001

6.6.2 General flocking behaviour

The Greater Adjutant Storks form very compact flocks. Barring some individuals, synchronization of activities was noticed which shows flock cohesiveness. Though at Urban Garbage Dump, due to widely distributed food, the GAS scattered for foraging, yet they followed each other in search of food. At Rural Garbage Dump, the flock was more compact and generally the whole flock used to move in one direction. However, when the rivulet was over flooded and submerged the dry barren land, the flock became loose and they dispersed in different directions for foraging in search of life prey. Sometimes the flock was divided into two or three smaller groups due to the disturbance by man or dog. Though at Urban Garbage Dump the GAS used to forage...
Plate 9a. The Greater Adjutant Storks foraging in an inundated paddy field during the breeding season.

Plate 9b. The Greater Adjutant Storks foraging in a semi-urban marshy area during non-breeding season. Note the non-breeding plumage.
very near to garbage collectors, at Nagaon occasionally they were chased by man and
dog.

Some activities were contagious: for example, wing stretching. If it was started by one
stork, simultaneously almost the whole flock followed but this activity lasted for a brief
period only, sometimes less than a minute. Generally this activity was seen at noon or
when the sun came out after rain. I found vultures also showed this behaviour along
with the GAS. When the storks started soaring they were found to take wing together
and once at Rural Garbage Dump whole flock was absent for more than 30 minutes.
Soaring was usually seen at noon when the thermal up current is formed.

The most common activity seen in the GAS flock was resting. They were found to take
rest in different positions. During resting they stand either on two legs or sometimes on
one leg. In the later case a GAS stands on one leg and it bends the other leg and
places just above the knee of the standing leg grasping it. Sometimes, they used to
squat down on the ground.

The GAS feed on small food items, (e.g., stomach contents of dead animals) by just
picking up the food in successive quick pecking. They do not throw the larger food into
the air like egrets do, instead they swallow the food by tossing the head forward and
backward. I saw GAS swallowing dry bone. Once at Nagaon, a GAS hunted an Indian
Myna Acredotheres tristis, all of a sudden when a small group of them were foraging
near the GAS. The mynas dispersed in panic making various noises but after some
time they again started to feed near the flock of GAS. P. C. Bhattacharjee (pers.
Plate 10a. The Greater Adjutant Storks foraging in the Urban Garbage Dump at Guwahati. Note the close proximity to human being.

Plate 10b. The Greater Adjutant Storks in the Rural Garbage Dump at Nagaon.
comm.) saw a GAS hunt a House Crow Corvus splendens at Guwahati garbage dumping ground.

A spectacular mass drinking by storks was seen at Rural Garbage Dump. The storks at Urban Garbage Dump used to drink water from small pools and ditches where one to three storks can drink at a time, but at the former site (Nagaon) they used to drink water from a rivulet together. When one stork starts walking towards the rivulet other storks also follow the leader and they march to the rivulet in a row. However, from the starting point they do not march in straight direction towards the rivulet, instead they march in a angular direction of 30° to 40° from the starting point. They drink water by scooping motion of the bill. Generally this behaviour was seen during the hot hours of day.

Fighting usually occurs during foraging. If one GAS finds a good piece of meat, other GAS follow it to snatch away the meat piece and they chase each other. However, sometimes frontal bill clash also took place when two GAS approached each other. They would poke at each other’s head ferociously in quick succession.

Generally the flock moves gradually by walking. Flying for short distance was seen at Rural Garbage Dump when they crossed the rivulet, and at Urban Garbage Dump when trucks brought garbage they sometimes flew to reach the food.

It was seen that in a flock, at least some storks were alert throughout the day. During the alert posture, a stork would stand erect with the body axis nearly vertical, the head elevated with extended neck and the bill held horizontally and they look around in suspicious mood. The alertness posture was not always in response to the threat of an
'intruder', but sometimes for looking for food from a distance. In the later case they also move gradually in this posture.

The stork used to come usually to the foraging ground early in the morning more or less in a single flock, but while leaving for roosting they go one by one at a very short interval so that the whole flock disappears within one hour. Before going for roosting they show typical alert posture looking around and then would follow other storks.

The competition among crows, vultures and storks for food was observed at Urban Garbage Dump throughout the day, while at Rural Garbage Dump it was seen only during early morning, sometimes before the data collection began. However, due to the difference in the foraging behaviour in these birds, different niches existed to reduce the competition. When a carcass was brought, vultures attacked first and storks were found to wait for the torn flesh. Though sometimes storks snatched food away from the vultures, usually vultures were found to dominate over the newly brought carcass and only few storks were found gathering near the carcass. After finishing most of the flesh by the vultures, storks were found to feed on the remnants. They were also found to forage in search of smaller dead bodies.

6.7 DISCUSSION

Most theories of why birds form flocks focus on adaptive advantages related to predators and/or food (Lack, 1968; Murton, 1971; Ward and Zahavi, 1972 and Bertram, 1978). Birds in flock can detect a predator well in advance and protect themselves than a solitary bird. Flocking birds can exploit patchy food resources more efficiently.
However, Rahmani (1991) found in Great Indian Bustard *Ardeotis nigriceps* that foraging in a flock does not play a significant role in locating food. Tacha *et al.* (1987) also found no association between flock size and percentage of time spent foraging by Sandhill Cranes *Grus canadensis* during winter and spring. On the contrary Saino (1994) found that in all range of flock sizes, crows in flocks have higher feeding rates than crows alone. Elgar (1989) proposes that feeding rate increases with the size of the flock because of competition for a common resource. He also argues that food density is an important confounding variable and the relationship between bird’s scanning and flock size is the consequence of the relationship between pecking rate and food density. Foraging rate increases with the high density of food and this attract larger flocks.

In the light of above statements, difference in the percentage number of storks involved in different activities at Urban Garbage Dump (Guwahati) and Rural Garbage Dump (Nagaon) can be discussed. Foraging is the main activity of flocking birds in non-breeding season during which they acquire required amount of energy for gonad formation for the next breeding season. Other associated activities are more or less related to foraging which in turn is connected with food availability in the foraging ground. Through this angle I shall discuss why the percentage number of storks at these two sites was different in different activities. In other words, why the proportion of activities were different at two different habitats.

At Guwahati garbage dump, availability of food for scavengers was more and there was continuous food supply almost throughout the day which attracted a large number of GAS. Therefore I noticed more foraging activity at Urban Garbage Dump than at the
Rural Garbage Dump where food supply was limited. Same situation is seen in Uganda where Marabou Storks *Leptoptilos crumeniferus* gather in large number in big refuse tips (Pomeroy, 1973) where like at Guwahati garbage dump truck-loads of refuse arrive every day. However, he observes that there is no obvious correlation between the food supply and number of storks. As has been mentioned above, different authors’ views about the relationship between foraging and size of the flock, it seems unlikely that due to the larger number of GAS, the foraging activity was enhanced than at Urban Garbage Dump Rural Garbage Dump. Due to limited food availability at Nagaon foraging site, less number of storks were found foraging. The other activities such as locomotion and fighting are related to foraging and hence they were more at Urban Garbage Dump. The GAS at Urban Garbage Dump used to follow the incoming trucks and as soon as the trucks were unloaded they would move there in search of food. Also, the movement of garbage collectors compelled them to move. The situation at Rural Garbage Dump was entirely different. So more storks were found resting and preening than those of Urban Garbage Dump.

Tacha (1988) found in Soundhill Cranes that higher the density of birds in a flock, the higher was the agonistic encounter rate and it was more while they were feeding. Watts (1985) suggests that competition increases with group size. An increase in flock size can also result in higher rates of aggression (Caraco, 1979). More storks were seen fighting and chasing each other at Urban Garbage Dump mainly for food. Therefore, it can be concluded that larger groups and more foraging activity lead to more agonistic behaviour in GAS.

The relationship between flock size and alertness or so-called vigilance has been studied by many workers (see Elgar, 1989 and references therein). Most of them are of
the view that there is a negative correlation between group size and vigilance rates. However, Elgar (1989) believes that decrease in vigilance levels in larger groups could be the result of competition for food. My result shows that more GAS were alert at Urban Garbage Dump (Guwahati) than at Rural Garbage Dump (Nagaon) where smaller number of GAS were found than at the former site. Thus it appears that larger flock size did not have any related effect on the alertness of GAS at Guwahati. This can be explained in other way also. Though the storks at Guwahati garbage dump have learned to coexist with man, yet due to the continuous disturbances they were more alert than the storks at Nagaon garbage dump. They were also alerted after seeing the incoming trucks and then anxiously waited for unloading of garbage.

Though visually it was seen that drinking behaviour of GAS at Guwahati was different with the GAS of Nagaon, statistically there is no significant difference between the percentage number of storks drinking at both sites. This could be due to the fact that this activity was not frequent and could have been missed in the observation period. Brown et al. (1982) report that Marabou Storks drink after swallowing a prey. However, I have not seen such post-swallowing drinking in GAS. The drinking was usually seen during noon, probably related with thermoregulation.

McNamara and Houston (1986) have suggested that animals face different energetic requirements according to the time of day. My study reveals that except for some activities, the general trend of the storks involved in different activities at these 'artificial' foraging grounds remained almost similar. Tamisier (1976) states that feeding before and during the colder portions of the day, and resting and preening during the warmer periods, probably achieves a thermodynamic advantage. Poysa (1994) found that
feeding and vigilance activity of teal *Anas crecca* did not vary significantly in different time periods. However, it is seen that at Urban Garbage Dump gradually more percentage of storks were involved in resting as the day progressed. But at Rural Garbage Dump proportion of this activity was almost same. This could be because the food supply at Urban Garbage Dump was continuous and unlimited throughout the day most of the storks would take sufficient food in the first half of the day itself and spend the afternoon time in resting. On the other hand, food availability at Rural Garbage Dump was very limited so GAS spent more time looking for food and hence, less time was available for nesting. This could be true because in 1995 I noticed their arrival from nearby roosting trees in flocks at dawn and sometimes in darkness.

Locomotion and fighting are associated with foraging activity. More storks were seen taking part in these activities at noon. This is probably because more storks from other areas joined the flock. However, Saino (1994) found that agonistic encounter in Carrion Crows *Corvus corone corone* do not vary significantly with food density or time of the day. Burger (1980) observed in Black-necked Stilts *Himantopus maxicanus* that though aggression was infrequent during most part of the day, it occurred with some regularity in the early morning when most birds fed vigorously.

Elgar (1989) states that vigilance rates may be lower at the beginning and at the end of the day because animals must either replenish energy reserves in the morning or store up energy reserves that will maintain them overnight. But at Guwahati garbage dump more storks were alert in the morning. As I have mentioned earlier that the alert posture was not only shown for fear or disturbance from garbage collectors, but also to show restlessness for attacking food brought by the trucks. This behaviour was shown by
more storks in the morning because many trucks brought garbage in the morning. On the other hand, at Rural Garbage Dump more alertness was seen in the afternoon. As has been mentioned already that a typical alertness is shown by every stork just before leaving for roosting, more storks at this site were seen alert at this period. Though at Urban Garbage Dump also storks show similar behaviour but compared to this, more storks were alert in the morning. Therefore at the two study sites, the percentage of storks showing this activity varied at different time of the day.

It seems that fluctuation in weather condition and cloud cover have very little impact on the activities of storks in a garbage dump. I experienced bright, cloudy and rainy days during the observation period at both the places. Though at the start of rain, storks initially stopped foraging or doing any other activities, soon they were found to resume their earlier activities. Wing stretching is a typical behaviour of storks. Marabou Storks also do this activity when sun emerges on a cool day (Brown et al., 1982). This activity is probably to dry up wings from rain water or dew, or to get rid of ectoparasites. The GAS bears many biting shaft Lice of the species Menopon gallinae inside its feather (Singha et al., in press).

It has been mentioned in section 6.6.1 that there was a significant difference in the activities of adults and juveniles. This difference was strongly significant in foraging activity. In all animals, juveniles and adults differ to some degree in their diets and foraging behaviour (Marchetti and Price, 1989). Even when independent of their parents, the diets and feeding techniques of juveniles commonly differ from those adults in the same area. Burger (1980) found that while foraging in a flock the Black-necked Stilt adults differ with the juveniles in many aspects: inter-food time interval,
time of foraging, in searching for food. Tacha (1988) reports that adult Sandhill Cranes spend more time in agonistic behaviour than juveniles. On the contrary, Rahmani (1991) found no significant difference in the peck rate of adult and juvenile Great Indian Bustard which foraged together in the same areas. Marchetti and Price (1989) have reviewed the differences of juvenile and adult birds (see also references therein) and conclude that these differences might be due to morphological constraints (e.g., bill, immaturity), lack of experience, combination of morphological and experiential constraints on juveniles. In GAS too, different percentage of juveniles and adults involved in foraging and other associated activities possibly attribute to the above reasons.

It was observed that during the non-breeding period, at garbage dumps, most of the storks pass the day resting and preening. Similar behaviour is shown by the Marabou Storks. On rubbish dumps, they spend many hours standing almost still, often squats on breast, occasionally pacing slowly a short distance (Brown et al., 1982). In fact, most of the behaviour of GAS during the non-breeding season resembles with that of congeneric Marabou Storks (see Brown et al., 1982; Pomeroy, 1973 and Pomeroy, 1975). Pomeroy (1975) considers Marabou Storks as facultative scavengers and assumes that scavenging behaviour evolved in this species before their food supply was augmented by man. Like GAS, they are also found to forage in urban refuse, abattoirs and fishing villages. Pomeroy (1973) divided food sources of Marabous into two categories: natural and other types of food which include fish, urban refuse and discarded parts from slaughter houses. They forage with other scavengers. As I have reported about food robbing from vultures by GAS, the same behaviour is shown by Marabous also (Brown et al., 1982). Hiraldo et al. (1991) found that White Storks
Ciconia ciconia frequently displace other scavenging birds from a carcass. At Rural Garbage Dump, though food availability was low, still the GAS were seen foraging in the barren field. They picked up dry bones, bone shaped hard objects and sometimes their own dropped feather. Pomeroy (1975) reports that Marabous also pick up any small objects lying on the ground.

Though Hancock (1989) has described the GAS as basically a carrion and large fish eater, I would say, they are opportunistic feeder. Unlike their African counterpart Marabou Storks, in which natural food plays a very small part in their normal life, the GAS are not found solely depended on scavenging in garbage dumps. I have seen drastic change of behaviour whenever there was heavy rainfall during the non-breeding season and low lying areas were inundated, they dispersed and foraged there in search of live prey. Compared to other activities they were found to forage there most of the time. The more resting activity seen at garbage dump could be of two reasons. At Guwahati garbage dump, probably they get enough ‘readymade food’ and they need not have to search for food for long time. At Nagaon garbage dump, though there was low food availability, they had no other food source to forage. it can be assumed that due to two different habitats with different amount of food source behaviour of the GAS varied.

The non-breeding season of the GAS is very brief compared to the long breeding season during which most of storks leave these regular foraging grounds and forage in shallow wetlands (pers. obs.). I suppose that during the non-breeding summer months, when shallow waterbodies dry up, due to their scavenging habit they take the opportunity to exploit these readymade foraging grounds. Otherwise, I believe, their
first option is live prey, hence even during the non-breeding period they go for foraging in inundated areas which are temporarily created by early monsoon rain.
REFERENCES


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